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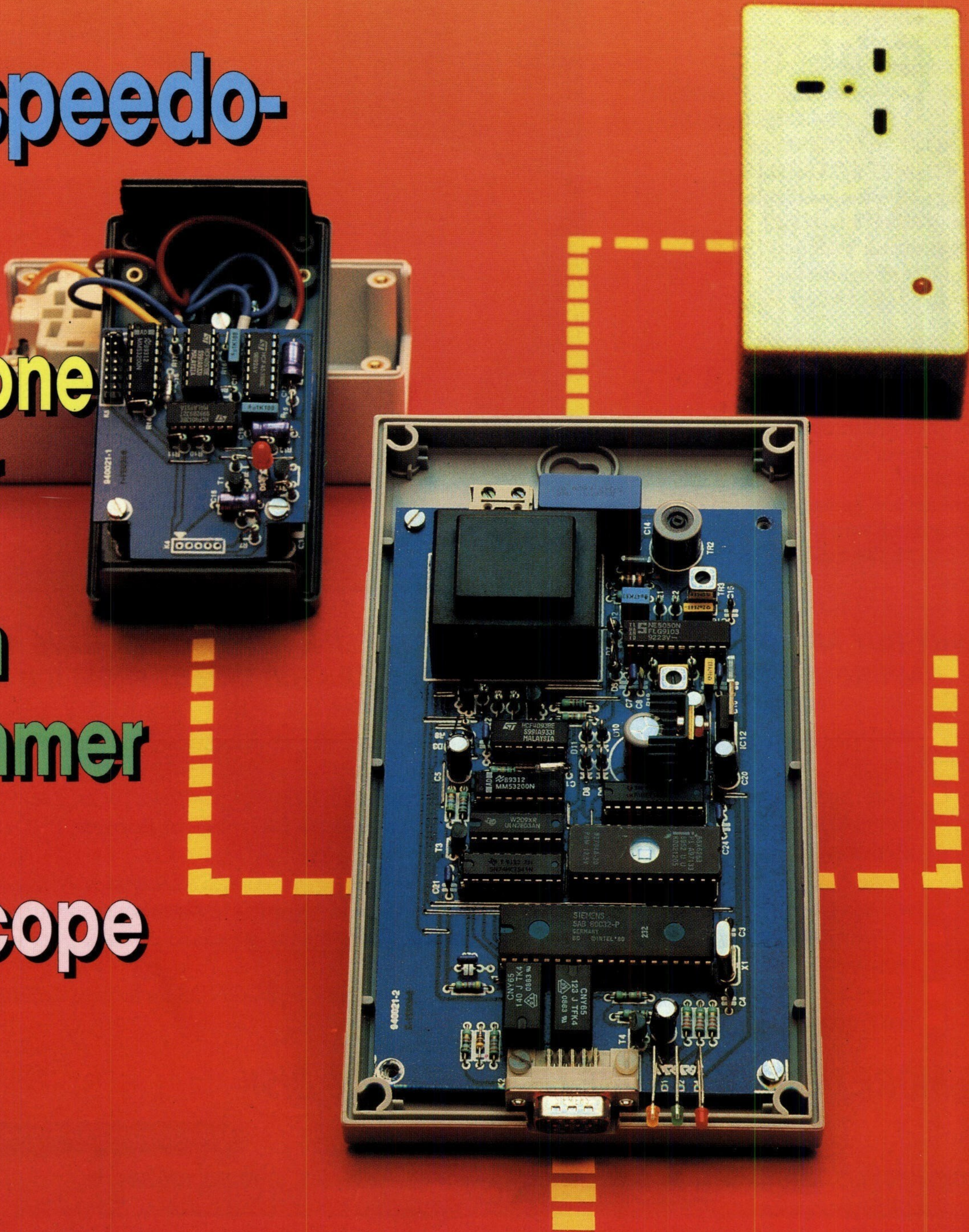

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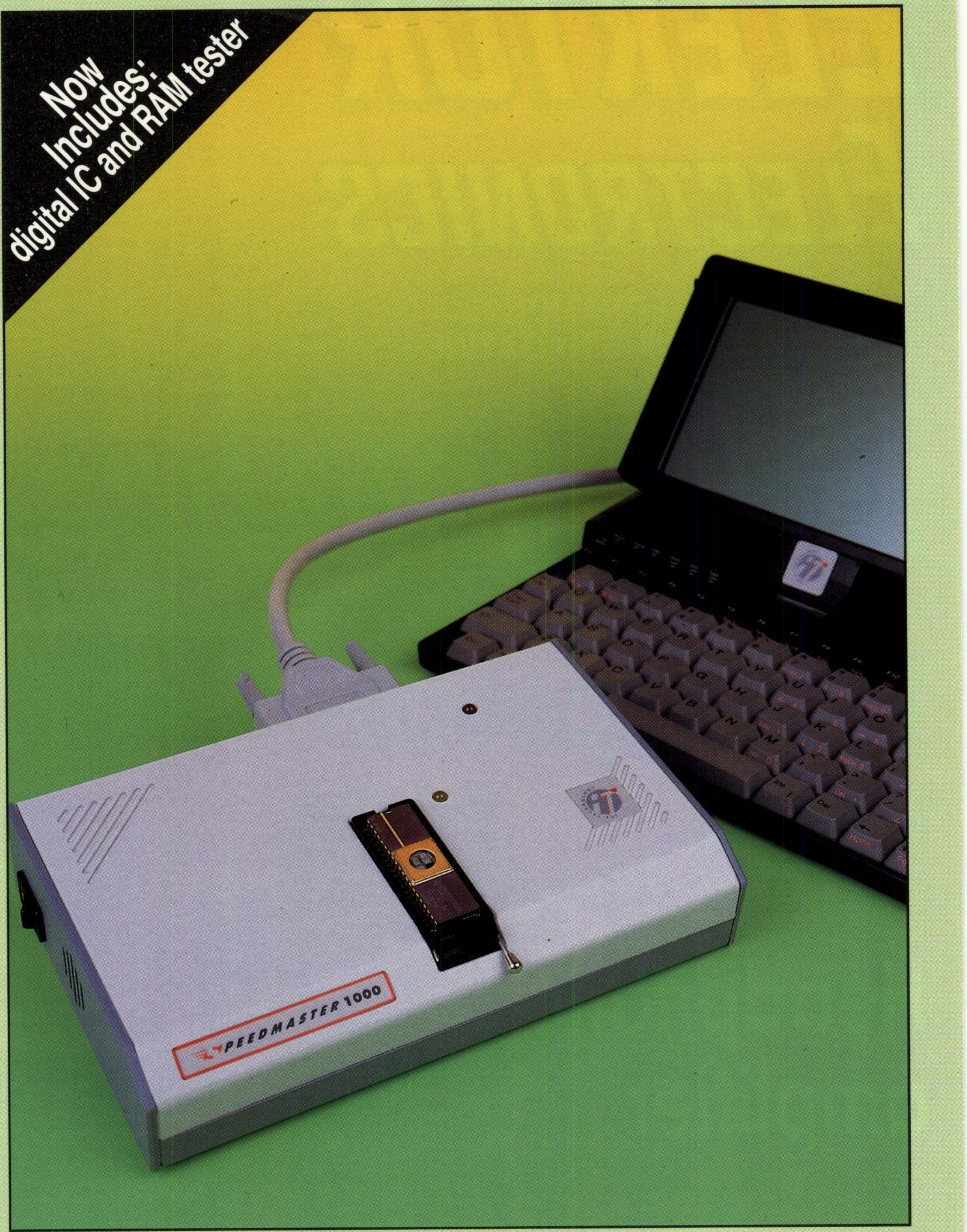

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Front cover
The photograph shows the receiver of a mains signalling system for home automation, of which the first part (of a two-part article) is discussed on page 42. Mains signalling is a method by which signals can be superimposed on mains wiring for the remote control of electrical equipment. The technique is well established in the USA, but in this country and Europe interest in it as a medium for communications has begun only in the late 1980s.

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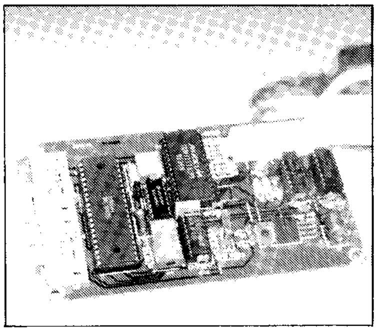

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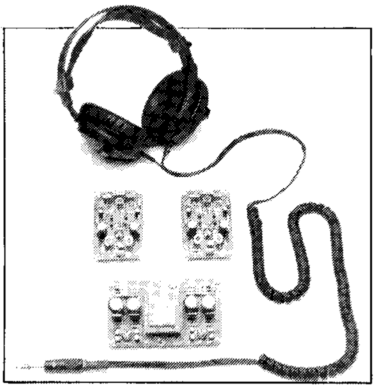

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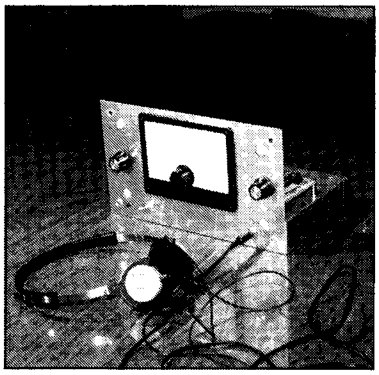

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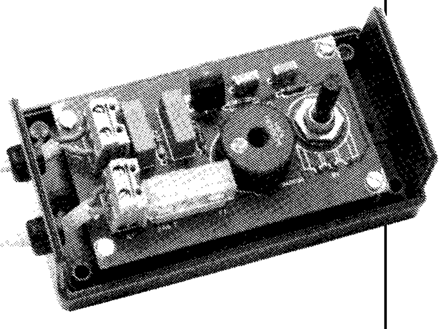

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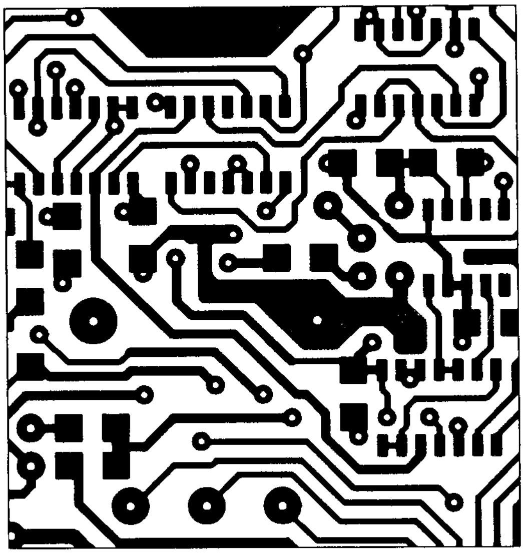

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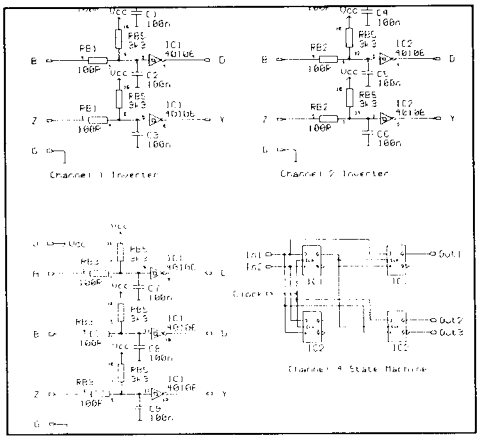

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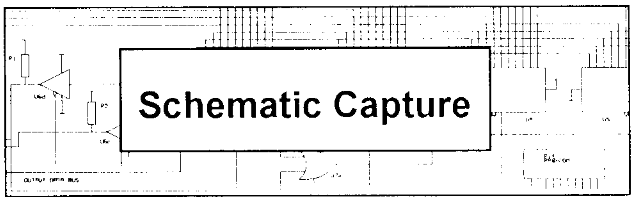

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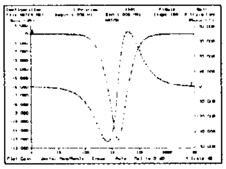

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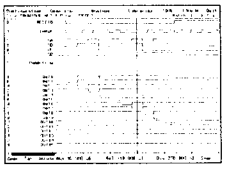

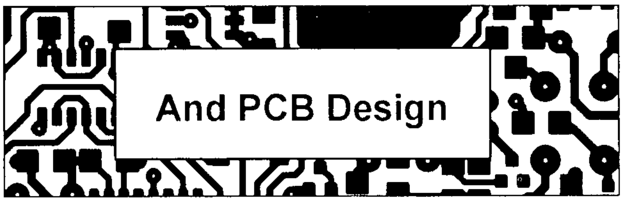

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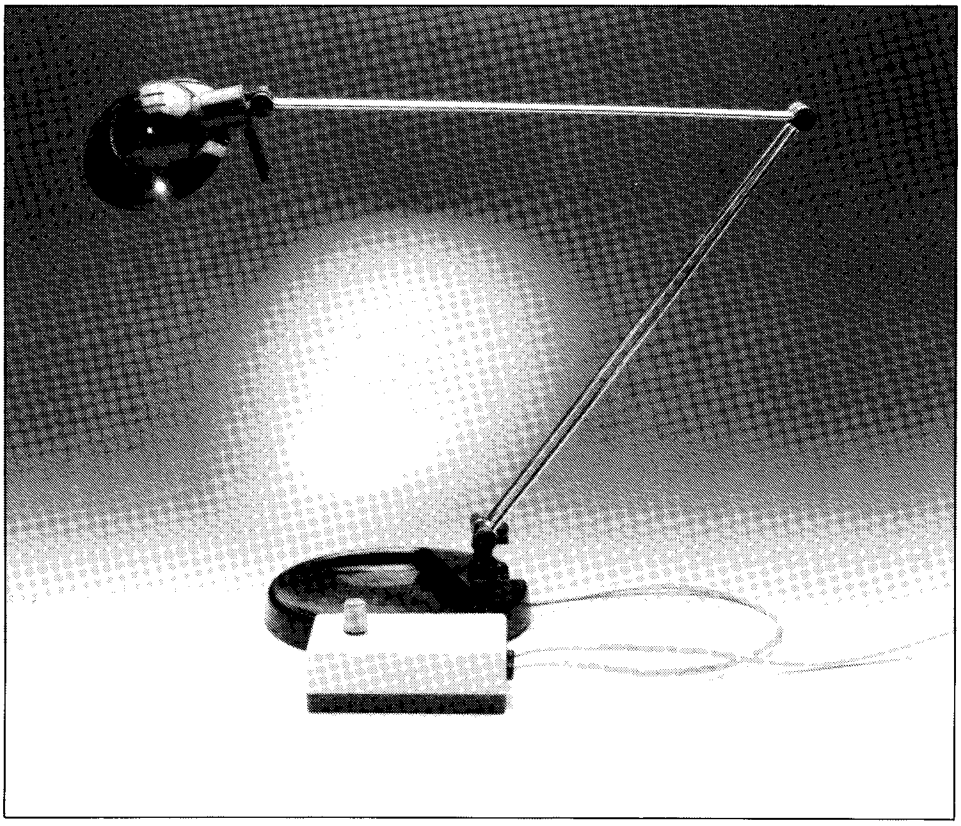
HALOGEN LIGHT DIMMER



The popularity of halogen light is still increasing, and rightly so because of some distinct advantages: the colour temperature is agreeable and excellent to work by, the efficiency is relatively high, and the lamps are powered by a low voltage. One disadvantage of halogen lights is rarely mentioned, however, although it is pretty obvious: conventional light dimmers can not be used. In this article an ingenious circuit is described to overcome that disadvantage.

Design by T. Giesberts

THERE are several ways of controlling the intensity of a lamp. The simplest and most obvious of these is to insert a high-power adjustable resistor in the supply line to the lamp. Theoretically, there is no objection against this solution. In practice, however, the power lost (in the form of heat) via the resistor increases as the lamp intensity is reduced. Again, this is no problem in theory, but most of you will balk at the energy waste caused by a red-glowing resistor and a lamp lighting at, say, a quarter of its nominal intensity. Fortunately, the series resistor method has never made it to large scale use with halogen lights, and it is easy to see why.

A much more elegant alternative is the adjustable transformer, or autotransformer, which held a very strong position for quite some time as a light dimmer in theatres and cinemas. With the arrival of thyristors and triacs, the autotransformer soon disappeared, and the principle of voltage control was replaced by phase control.

Phase control

Although an autotransformer is an interesting piece of technology, it is a fairly costly and cumbersome device. These disadvantages do not apply to the competitive technique, phase reduction, also known as phase control or phase cutting. Light dimmers operating on this principle are just as compact and inexpensive as the previously mentioned adjustable resistors, but that is as far as the comparison goes because they are virtually free from the 'energy waste' disadvantage.

Phase control is achieved with the aid of a fast electronic switch (usually a triac), which is driven in such a way that it is closed during a section of the each period of the alternating supply voltage. In this way, pieces are 'cut out' of the phase. During the time the switch is open, no current flows, so no energy is wasted in the regulating device. The operation of the phase control is illustrated in **Fig. 1**. As soon as the alternating voltage is past the zero crossover point, and about to increase in the positive or negative direction, a capacitor is charged via an *RC* network. Almost instantly, the triac is fired (triggered) by a pulse generated by the charged capacitor. The triac starts to conduct, and switches on the lamp. The lamp lights only briefly, however, because the triac stops to conduct as soon as the current which flows through the device drops below the so-called 'hold' level. That happens, obviously, when the alternating voltage reaches the next zero crossover point, which causes the triac to be switched off, and wait for the next trigger pulse.

By comparing the left-hand and right-hand section of **Fig. 1**, it becomes clear how the intensity of the lamp can be made adjustable. By including a potentiometer in the previously mentioned *RC* network, the instant at which the capacitor is sufficiently charged to furnish the trigger pulse, becomes variable. If an 'early' instant is set (left-hand part of **Fig. 1**), the triac will conduct the largest part of each half period. Consequently, the lamp will light at an intensity just below its maximum. By increasing the *RC* time (right-hand drawing), the triac is fired much later, so that the lamp lights much shorter. If the firing pulse arrives just before the next zero crossing, the lamp will hardly light because it is on for a very small part of each half period.

Phase control with halogen lights

Unfortunately the transformer used with halogen lights makes it impossible to apply the above principle of phase cutting straight away to achieve intensity control. While a normal incandescent lamp forms a fairly 'neat' non-reactive load, the transformer used to step down the mains voltage to the halogen lamp supply voltage of 12 V or 24 V is a highly inductive load.

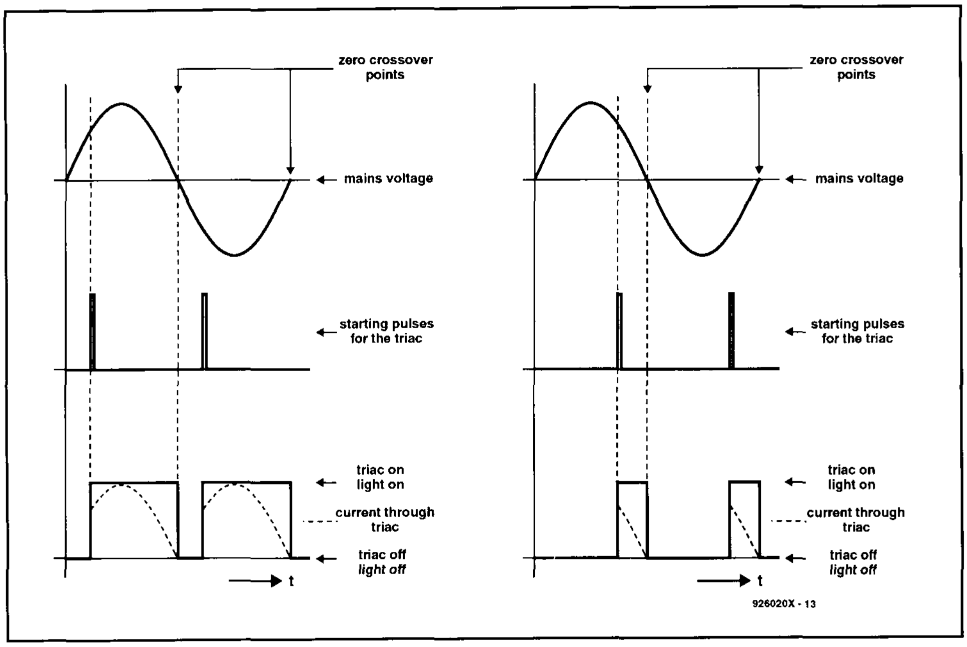


Fig. 1. In a phase reduction dimmer circuit, the lamp is only on for an (adjustable) part of each half period of the alternating supply voltage. This is achieved with the aid of a triac, which is triggered by an *RC* circuit, and switched off again (automatically) on each zero crossover point of the alternating voltage.

Consequently, current and voltage are not in phase, causing a lot of trouble. Assuming that a phase control circuit is used to 'dim' a transformer, it will often happen that a firing pulse arrives at the triac gate when the current, instead of the voltage, passes a zero crossover point. If that happens, the triac can not possibly start to conduct because it passes a current which is below the hold level. The result of the reactive component presented by the transformer primary is erratic behaviour of the control.

Can we do something about that? The first solution would appear to use a triac with a very low hold current, because that reduces the risk of faulty triggering considerably. However, this is considered 'cheap' by many, and goes round the actual problem. The real solution obviously lies in conditioning the trigger pulse. Two options are available: (1) the firing pulse may be made wider so that it lasts beyond zero crossings of the current, should these occur, or (2) each pulse is repeated a couple of times at very short intervals.

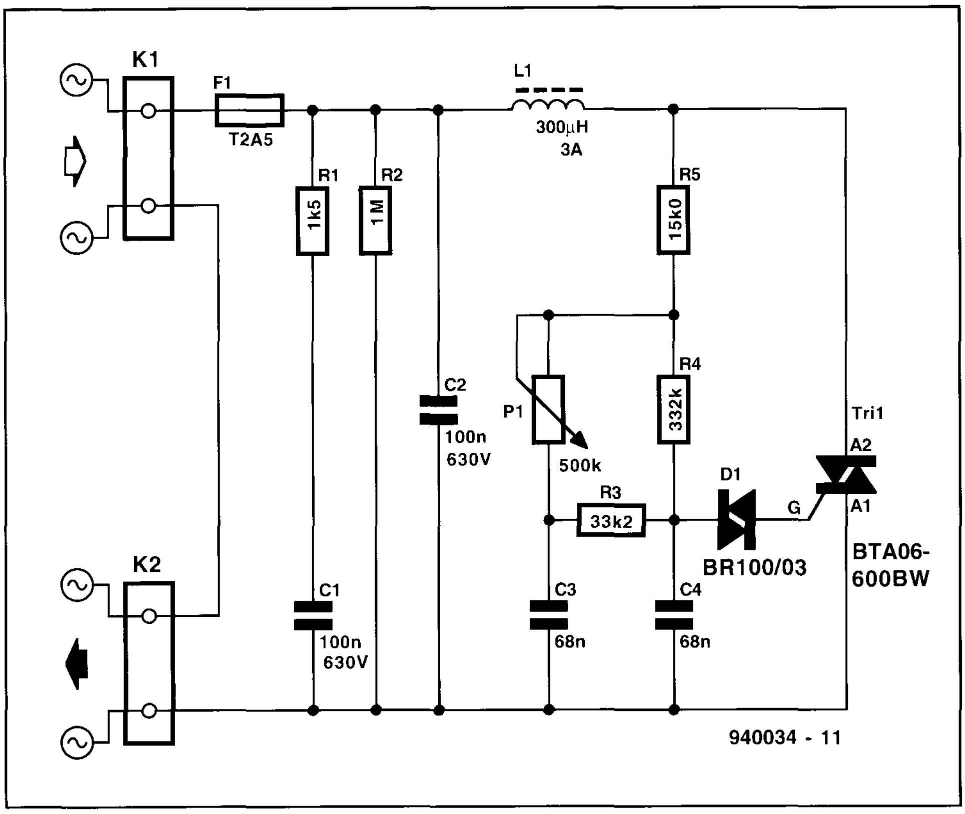


Fig. 2. To make sure that the dimmer operates reliably with the inductive load presented by the transformer primary, the RC network is extended with a capacitor to provide a burst of trigger pulses, rather than a single pulse.

The second option is adopted for the present circuit, and a glance at the circuit diagram in **Fig. 2** shows the practical implementation.

The triac control proper is shown in the right-hand part of the diagram. Forgetting about C_3 for a moment, i.e., assuming P_1 and R_3 to shunt R_4, leaves you with an ordinary dimmer circuit. Capacitor C_4 is charged via resistors R_3, R_4, P_1 and R_5. After a certain time, which is adjustable with P_1, the charge contained in C_4 is large enough for diac D_1 to start conducting, so that a firing pulse is applied to the gate of triac Tri$_1$. Consequently, the triac conducts, and so forms a connection between K_1 and K_2, i.e., the input and the output of the dimmer circuit. So far, nothing new.

The operation of the circuit is made special by the capacitor we 'forgot about' in the above description. In fact, C_3 is charged virtually simultaneously with C_4, and functions as a reservoir device for the latter. Immediately after D_1 starts to conduct, and a part of the charge of C_4 has 'disappeared' in the gate of Tri$_1$, the capacitor is almost instantly recharged by C_3 via R_3, causing another trigger pulse at the triac gate. This happens a couple of times, so that the triac gate is fed with bursts of three or four trigger pulses. The triac trigger burst is shown in the oscillogram in **Fig. 3**.

The remainder of the circuit is all plain sailing, and requires hardly any further explanation, since the components used are found in nearly every dimmer circuit. Briefly, network R_1-C_1 prevents voltage surges caused by the inductive load from 'killing' the triac. The combination of inductor L_1 and capacitor C_2 keeps the spurious signals caused by the trigger circuit away from the mains lines, where they would give rise to interference in other equipment. Resistor R_2, finally, acts as a 'bleeder' across capacitor C_2, preventing dangerous voltages on the circuit output when the load is disconnected.

The triac used in the dimmer, finally, is just the thing for the present application: it has a hold current of only 50 mA, and is capable of withstanding short pulses of up to 63 A!

Building the dimmer

For ease of construction as well as for safety's sake, the dimmer is best built on the printed circuit board shown in

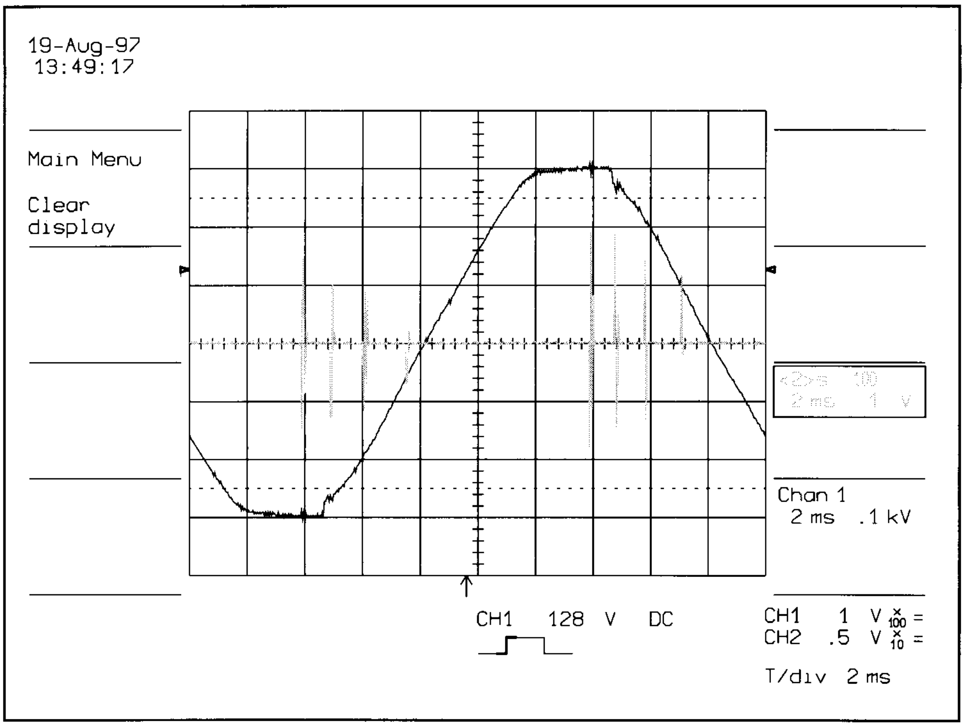


Fig. 3. LeCroy 9410 oscilloscope screendump showing the trigger burst and the alternating supply voltage. If one of the pulses in the burst happens to coincide with the zero crossover point, there is always another to trigger the triac.

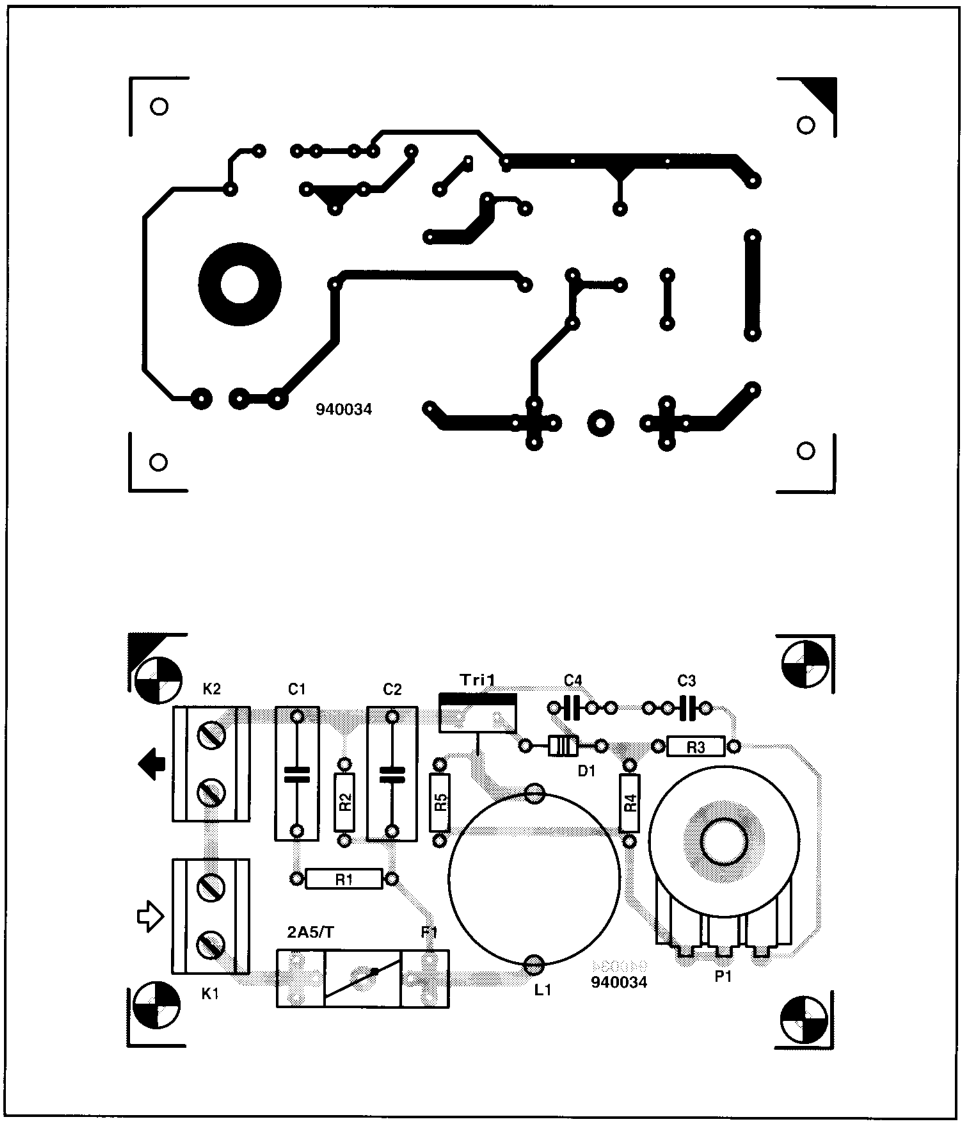


Fig. 4. Populating this printed circuit board should not take you more than half an hour or so (PCB not available ready-made through the Readers Services).

Fig. 4. Unfortunately this PCB is not available ready-made through our Readers Services, so you have to etch and drill it yourself.

Construction should be easy for the 'average' home constructor. Be sure, however, to pay attention to the specifications of the components used. Capacitors C_1 and C_2 must be rated at 630 VDC, and potentiometer P_1 must be a type with a plastic spindle. Do not use an ordinary choke for L_1, but a real suppressor choke capable of handling up to 3 A. The triac can make do without a heat-sink if the load current does not exceed about 1 A (*P* approx. 200 W). If you intend to use the dimmer for higher currents (for instance, for a 300-W ceiling uplight), the triac must be fitted with a small heatsink. The maximum current the circuit is capable of supplying is about 2.5 A (approx. 500 W).

Since a dimmer is invariably connected directly to the mains, every precaution should be taken to ensure electrical safety. **Most parts in the circuit are at mains potential, and are, therefore, extremely dangerous to touch. Never touch any part while the circuit is connected to the mains. Always disconnect the circuit from the mains before doing any measurement or adjustment.** Mount the dimmer in an all-ABS enclosure, and provide sturdy grommets and strain reliefs on the mains cables connected to K_1 and K_2. ■

COMPONENTS LIST

Resistors:
R1 = 1kΩ5 1%
R2 = 1MΩ 1%
R3 = 33kΩ2 1%
R4 = 332kΩ 1%
R5 = 15kΩ0 1%
P1 = 500kΩ linear w. plastic spindle

Capacitors:
C1;C2 = 100nF 630VDC
C3;C4 = 68nF

Semiconductors:
D1 = BR100/03 diac
Tri1 = BTA06-600BW (SGS-Thomson)

Miscellaneous:
L1 = 300μH 3A suppressor coil, e.g., Newport 1430430
K1;K2 = 2-way PCB terminal block, pitch 7.5mm
F1 = fuse 2A5 slow, w. PCB mount holder
Enclosure: e.g. OKW A 90 20 087 (65x20x40mm)
2 strain relief clamps

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4013B	0.20
4014B	0.42
4015B	0.42
4016B	0.24
4017B	0.38
4018B	0.38
4019B	0.26
4020AE	0.36
4020B	0.38
4021B	0.40
4022B	0.40
4023B	0.20
4023UB	0.23
4024AE	0.27
4024B	0.32
4025B	0.19
4026B	0.54
4027B	0.30
4028B	0.38
4029B	0.35
4030B	0.21
4031B	1.04
4032B	0.70
4033B	0.58
4034B	1.10
4035B	0.39
4036B	2.57
4037B	1.27
4038B	0.78
4039B	3.22
4040B	0.42
4041B	0.41
4041UB	0.32
4042B	0.32
4043B	0.36
4044B	0.36
4045B	0.94
4046B	0.42
4047B	0.38
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4093B	0.24
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4095B	0.70
4096B	1.10
4097B	2.75
4098B	0.40
4099B	0.42
4104P	1.01
4160B	0.85
4161B	0.85
4174B	1.27
4175B	1.14
4194B	1.43
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4410P	16.45
4411P	21.58
4412FP	POA
4412FL	POA
4412VP	POA
4416P	POA
4419P	POA
4429PB	POA
4433P	POA
4443P	POA
4447P	POA
4468P	POA
4469P	POA
4489P	POA
4490P	3.20
4495P	6.27
4497P	13.58
4499P	6.24
4500B	19.45
4501B	0.32
4502B	0.38
4503B	0.38
4504B	1.12
4505B	4.42
4506B	1.14
4506U	1.14
4508B	1.14
4510B	0.54
4511B	0.44
4512B	0.38
4513B	1.20
4514B	1.12
4515B	1.12
4516B	0.44
4517B	1.84
4518B	0.40
4519B	0.36
4520B	0.36
4521B	0.72
4522B	0.86
4526B	0.50
4527B	0.56
4528B	0.49
4529B	0.57
4530B	1.92
4531B	1.14
4532B	0.44
4534B	2.82
4536B	1.22
4538B	0.60
4539B	0.62
4541B	0.52
4543B	0.57
4544B	2.11
4547B	1.68
4549B	POA
4551B	1.62
4553B	2.37
4554B	6.01
4555B	0.48
4556B	0.49
4557B	1.88
4558B	2.18
4560B	1.51
4561B	1.74
4562B	5.15
4566B	1.10
4568B	5.17
4569B	3.04
4572UB	0.70
4573P	POA
4580B	8.84
4581B	3.85
4582B	3.85
4583B	0.86
4584B	0.57
4585B	0.49
4597CP	6.90
4598B	6.90
4599B	5.50
4720B	POA
4720V	POA
4723B	POA
4724B	1.90
4731VP	9.80
4737VP	18.28
4738VP	18.50
4750VD	28.50
4752VP	29.25
4753VP	POA
4754VP	POA
40085	1.98
40097	0.62
40098	0.62
40100	2.48
40101	POA
40102	1.20
40103	0.88
40105	1.82
40106	0.30
40107	0.42
40108	POA
40109	1.24
40110	1.04
40114	2.62
40116	12.48
40117	1.80
40147	1.23
40160	0.54
40161	0.54
40162	0.54
40163	0.54
40174	0.34
40175	0.47
40181	POA
40192	0.62
40193	0.74
40194	1.82
40195	2.24
40240	2.62
40244	1.36
40245	1.36
40257	0.54
40373	1.10
40374	1.10
45026	4.42
45027	5.99
45028	4.49
45040	POA
45041	POA
45100	POA
45106	7.98
45109	POA
45138	POA
45145	10.04
45146	POA
45151	19.50
45152	21.45
45156	15.80
45157	14.38
45158	11.94
45159	POA
45406	2.73
45407	6.47
45411	POA
45414	15.60
45428	POA
45433	POA
45440	POA
45441	POA

4000 SERIES SURFACE MOUNT

4001BT	0.32
4002BT	0.32
4011BT	0.32
4011UBT	0.32
4012BT	0.32
4013BT	0.45
4015BT	0.84
4016BT	0.43
4017BT	0.78
4018BT	0.78
4020BT	0.95
4021BT	0.65
4023BT	0.38
4024BT	0.76
4025BT	0.38
4027BT	0.45
4028BT	0.56
4029BT	0.86
4040BT	0.78
4042BT	0.74
4046BT	1.41
4047BT	1.06
4049BT	1.06
4050BT	0.48
4051BT	0.78
4052BT	0.84
4053BT	0.98
4060BT	0.84
4066BT	0.59
4068BT	0.38
4069UBT	0.38
4070BT	0.38
4071BT	0.38
4075BT	0.38
4077BT	0.38
4078BT	0.38
4081BT	0.38
4093BT	0.45
4094BT	0.95
4508BT	2.05
4510BT	1.02
4511BT	1.35
4512BT	0.68
4514BT	2.20
4516BT	1.02
4518BT	1.18
4520BT	1.18
4521BT	1.07
4522BT	1.22
4528BT	0.88
4534BD	POA
4538BT	1.05
4541BT	1.05
4543BT	1.02
4555BT	POA
4556BT	1.05
4585BT	0.95
40106BT	0.53
40244BT	1.35
40373BT	2.34

74 SERIES

7400	0.36
7401	0.30
7402	0.34
7403	0.34
7404	0.40
7405	0.40
7406	0.68
7406A	0.72
7407	0.63
7407A	0.65
7408	0.37
7409	0.67
7410	0.35
7412	0.64
7413	0.76
7414	0.72
7416	0.53
7417	0.48
7420	0.37
7425	0.59
7426	0.48
7427	0.59
7430	0.35
7432	0.45
7437	0.59
7438	0.49
7440	0.77
7442	0.55
7445	1.20
7446	1.53
7447	0.98
7447A	1.67
7451	0.57
7454	0.72
7470	0.54
7472	0.38
7473	0.59
7474	0.53
7475	0.67
7476	0.72
7480	1.26
7483	1.10
7485	0.58
7486	0.53
7490	0.76
7490A	1.34
7491	2.56
7492	0.67
7492A	1.12
7493	0.68
7493A	0.70
7495A	1.10
7497	5.23
74104	0.67
74107	0.60
74110	POA
74116	3.10
74118	POA
74119	POA
74121	0.98
74123	0.94
74125	0.67
74126	0.98
74128	1.19
74132	0.86
74145	1.16
74150	1.86
74151	0.80
74151A	0.80
74153	0.90
74154	2.16
74155	0.81
74157	0.74
74158	1.57
74159	3.98
74160	0.94
74161A	0.98
74163	1.28
74164	1.20
74165	1.57
74166	1.06
74174	1.53
74175	1.23
74180	1.29
74184	POA
74185	1.76
74191	1.41
74192	1.41
74193	1.65
74221	1.23
74259	2.92
74265	1.46
74273	POA
74276	3.56
74279	1.38
74283	1.26
74298	POA
74365	0.70
74367	1.06
74393	2.94
74403	POA
74423	POA

74LS SERIES

74LS00	0.18
74LS01	0.18
74LS02	0.18
74LS03	0.18
74LS04	0.21
74LS05	0.21
74LS06	0.51
74LS07	0.51
74LS08	0.18
74LS09	0.18
74LS10	0.18
74LS11	0.18
74LS12	0.18
74LS13	0.19
74LS14	0.24
74LS15	0.38
74LS20	0.18
74LS21	0.18
74LS22	0.18
74LS24	0.58
74LS26	0.18
74LS27	0.18
74LS28	0.24
74LS30	0.18
74LS31	1.58
74LS32	0.20
74LS33	0.20
74LS37	0.18
74LS38	0.18
74LS40	0.18
74LS42	0.32
74LS44	2.11
74LS47	0.55
74LS48	0.54
74LS49	1.38
74LS51	0.19
74LS54	0.19
74LS55	0.32
74LS73	0.40
74LS73A	0.48
74LS74	0.22
74LS74A	0.24
74LS75	0.28
74LS76	0.68
74LS76A	0.72
74LS77	0.42
74LS78	0.32
74LS83	0.39
74LS83A	0.39
74LS85	0.38
74LS86	0.27
74LS90	0.40
74LS91	POA
74LS92	POA
74LS93	0.44
74LS95	0.48
74LS96	0.82
74LS107	0.28
74LS107A	0.38
74LS109	0.28
74LS109A	0.32
74LS112	0.28
74LS112A	0.34
74LS113	0.32
74LS113A	0.38
74LS114	0.32
74LS114A	0.36
74LS122	0.39
74LS123	0.36
74LS125	0.28
74LS125A	0.32
74LS126	0.32
74LS126A	0.36
74LS132	0.29
74LS133	0.18
74LS136	0.38
74LS137	0.98
74LS138	0.31
74LS139	0.34
74LS145	0.66
74LS147	2.86
74LS148	0.83
74LS151	0.32
74LS153	0.32
74LS154	1.12
74LS155	0.34
74LS156	0.38
74LS157	0.38
74LS158	0.34
74LS160	0.48
74LS160A	0.54
74LS161	0.46
74LS161A	0.49
74LS162	0.48
74LS162A	1.07
74LS163	0.42
74LS163A	0.47
74LS164	0.34
74LS165	0.59
74LS166	0.59
74LS168	0.75
74LS169	0.59
74LS170	POA
74LS173	0.39
74LS173A	0.44
74LS174	0.36
74LS175	0.34
74LS181	1.82
74LS182	2.05
74LS183	2.05
74LS189	2.60
74LS190	0.49
74LS191	0.49
74LS192	0.49
74LS193	0.48
74LS194	0.54
74LS194A	0.57
74LS195A	0.57
74LS196	0.68
74LS197	0.68
74LS221	0.44
74LS224	20.24
74LS240	0.42
74LS241	0.42
74LS242	0.42
74LS243	0.42
74LS244	0.42
74LS245	0.42
74LS247	0.44
74LS248	0.68
74LS249	0.99
74LS251	0.32
74LS253	0.44
74LS256	0.78
74LS257	0.34
74LS257A	0.46
74LS258	0.44
74LS258A	0.48
74LS259	0.48
74LS260	0.22
74LS266	0.32
74LS273	0.42
74LS275	POA
74LS279	0.33
74LS280	0.86
74LS283	0.45
74LS290	0.48
74LS292	16.86
74LS293	0.38
74LS294	17.82
74LS295	1.11
74LS295A	1.15
74LS298	0.98
74LS299	1.53
74LS321	3.82
74LS322	POA
74LS322A	POA
74LS323	3.24
74LS347	2.86
74LS348	1.98
74LS352	1.68
74LS353	1.68
74LS363	2.10
74LS364	POA
74LS365	0.30
74LS365A	0.34
74LS366	0.36
74LS366A	0.42
74LS367	0.29
74LS367A	0.34
74LS368	0.36
74LS368A	1.72
74LS373	0.38
74LS374	0.44
74LS375	0.42
74LS377	0.66
74LS378	0.98
74LS379	0.99
74LS381A	4.96
74LS385	3.48
74LS386	0.98
74LS390	0.46
74LS393	0.40
74LS395	0.66
74LS395A	0.94
74LS396	POA
74LS398	POA
74LS399	0.81
74LS423	0.98
74LS445	POA
74LS450	10.68
74LS461A	7.16
74LS465	3.82
74LS467	7.78
74LS468	7.78
74LS469	6.10
74LS469A	6.70
74LS490	2.85
74LS491A	12.82
74LS502	POA
74LS540	0.80
74LS541	0.80
74LS569	POA
74LS573	1.34
74LS574	1.34
74LS590	4.85
74LS592	5.28
74LS593	6.79
74LS595	4.85
74LS597	4.95
74LS621	POA
74LS622	POA
74LS623	2.98
74LS624	2.10
74LS625	5.37
74LS626	POA
74LS627	POA
74LS628	1.78
74LS629	1.98
74LS631	POA
74LS639	POA
74LS640	0.98
74LS641	0.98
74LS641-1	1.28
74LS642	0.98
74LS642-1	POA
74LS643	POA
74LS644	POA
74LS645	1.12
74LS645-1	1.28
74LS646	5.85
74LS652	POA
74LS669	1.07
74LS670	0.78
74LS673	POA
74LS674	17.60
74LS682	2.62
74LS683	POA
74LS684	3.85
74LS685	POA
74LS686	POA
74LS687	POA
74LS688	1.98
74LS693	POA
74LS794	POA
74LS795	POA
74LS796	POA
74LS797	POA
74LS848	POA

74HC SERIES

74HC00	0.19
74HC02	0.19
74HC03	0.24
74HC04	0.19
74HCU04	0.24
74HC05	0.20
74HC08	0.20
74HC10	0.29
74HC11	0.20
74HC14	0.25
74HC14A	0.34
74HC20	0.22
74HC21	0.22
74HC27	0.22
74HC30	0.22
74HC32	0.22
74HC42	0.48
74HC51	0.29
74HC58	0.42
74HC73	0.34
74HC74	0.25
74HC75	0.40
74HC76	0.40
74HC77	0.51
74HC85	0.48
74HC86	0.28
74HC93	0.44
74HC107	0.39
74HC109	0.35
74HC112	0.40
74HC113	0.40
74HC123	0.40
74HC125	0.40
74HC126	0.47
74HC131	0.52
74HC132	0.32
74HC133	0.32
74HC137	0.76
74HC138	0.34
74HC139	0.31
74HC141	0.61
74HC147	0.61
74HC148	0.55
74HC151	0.40
74HC153	0.40
74HC154	0.98
74HC155	0.69
74HC157	0.42
74HC158	0.47
74HC160	0.64
74HC161	0.42
74HC162	0.64
74HC163	0.42
74HC164	0.42
74HC165	0.55
74HC166	0.88
74HC173	0.76
74HC174	0.42
74HC175	0.36
74HC181	1.94
74HC182	0.59
74HC190	0.67
74HC191	0.52
74HC192	0.77
74HC193	0.54
74HC194	0.67
74HC195	0.47
74HC221	0.44
74HC237	0.73
74HC238	0.64
74HC240	0.44
74HC241	0.44
74HC242	0.80
74HC243	0.88
74HC244	0.43
74HC245	0.44
74HC251	0.35
74HC253	0.52
74HC257	0.47
74HC258	0.73
74HC259	0.65
74HC266	0.36
74HC273	0.54
74HC279	0.51
74HC280	0.89
74HC283	0.58
74HC298	0.73
74HC299	1.09
74HC323	1.58
74HC354	0.55
74HC356	0.65
74HC365	0.41
74HC366	0.52
74HC367	0.47
74HC368	0.52
74HC373	0.44
74HC374	0.44
74HC375	0.76
74HC377	0.51
74HC386	0.29
74HC390	0.38
74HC393	0.41
74HC423	0.64
74HC521	0.95
74HC533	0.95
74HC534	0.89
74HC540	0.69
74HC541	0.60
74HC563	0.88
74HC564	0.88
74HC573	0.64
74HC573A	0.72
74HC574	0.64
74HC589	1.64
74HC590	0.94
74HC592	1.19
74HC593	1.66
74HC595	0.92
74HC597	0.98
74HC620	1.62
74HC623	1.62
74HC633	1.62
74HC640	1.32
74HC643	1.32
74HC645	1.40
74HC646	1.77
74HC648	1.77
74HC651	1.47
74HC652	1.47
74HC658	4.49
74HC659	4.49
74HC664	4.49
74HC665	4.49
74HC670	1.10
74HC677	3.78
74HC678	5.91
74HC680	3.83
74HC682	4.21
74HC684	5.70
74HC688	0.87
74HC690	1.62
74HC691	1.62
74HC692	1.73
74HC693	1.73
74HC696	1.48
74HC697	1.24
74HC698	1.24
74HC699	1.24
74HC4002	0.35
74HC4015	1.07
74HC4016	0.44
74HC4017	0.42
74HC4020	0.52
74HC4022	0.56
74HC4024	0.50
74HC4028	0.58
74HC4040	0.50
74HC4046	1.54
74HC4049	0.48
74HC4050	0.36
74HC4051	0.64
74HC4052	0.68
74HC4053	0.68
74HC4053A	1.10
74HC4060	0.47
74HC4061	2.52
74HC4066	0.46
74HC4066A	0.54
74HC4067	4.72
74HC4072	0.45
74HC4075	0.32
74HC4078	0.46
74HC4094	0.64
74HC4316	0.68
74HC4351	0.89
74HC4511	0.55
74HC4514	1.38
74HC4515	1.42
74HC4518	0.80
74HC4520	0.72
74HC4534	0.00
74HC4538	0.68
74HC4543	0.81
74HC7001	1.01
74HC7002	1.01
74HC7032	1.01
74HC7266	0.84
74HC7074	1.99
74HC7292	1.10
74HC7294	1.10
74HC40102	1.10
74HC40103	1.10
74HC40105	1.40

74HCT SERIES

74HCT00	0.22
74HCT02	0.22
74HCT03	0.26
74HCT04	0.22
74HCT08	0.22
74HCT10	0.22
74HCT11	0.22
74HCT14	0.26
74HCT20	0.26
74HCT21	0.26
74HCT27	0.26
74HCT30	0.26
74HCT32	0.22
74HCT42	0.46
74HCT73	0.36
74HCT74	0.26
74HCT75	0.36
74HCT85	0.60
74HCT86	0.36
74HCT93	0.58
74HCT107	0.40
74HCT109	0.42
74HCT112	0.42
74HCT123	0.64
74HCT125	0.56
74HCT126	0.56
74HCT132	0.50
74HCT137	0.52
74HCT138	0.32
74HCT139	0.45
74HCT147	0.68
74HCT151	0.52
74HCT153	0.44
74HCT154	1.24
74HCT157	0.44
74HCT158	0.48
74HCT160	0.56
74HCT161	0.56
74HCT162	0.84
74HCT163	0.56
74HCT164	0.52
74HCT165	0.52
74HCT166	0.52
74HCT173	0.52
74HCT174	0.52
74HCT175	0.52
74HCT181	3.24
74HCT182	0.96
74HCT190	0.64
74HCT191	0.64
74HCT192	0.94
74HCT193	0.64
74HCT194	1.13
74HCT195	1.16
74HCT221	0.98
74HCT237	0.94
74HCT238	0.51
74HCT240	0.55
74HCT241	0.55
74HCT242	0.76
74HCT243	0.76
74HCT244	0.57
74HCT245	0.52
74HCT251	0.86
74HCT253	0.51
74HCT257	0.54
74HCT258	0.72
74HCT259	0.78
74HCT273	0.68
74HCT280	0.98
74HCT283	0.90
74HCT297	0.82
74HCT299	1.64
74HCT354	1.28
74HCT356	1.28
74HCT365	0.54
74HCT366	0.80
74HCT367	0.54
74HCT368	0.80
74HCT373	0.44
74HCT374	0.55
74HCT377	0.64
74HCT390	0.68
74HCT393	0.68
74HCT394	0.00
74HCT423	0.62
74HCT533	1.44
74HCT534	0.75
74HCT540	0.64
74HCT541	0.64
74HCT563	0.98
74HCT564	0.78
74HCT573	0.64
74HCT574	0.64
74HCT583	0.00
74HCT597	1.52
74HCT640	1.34
74HCT643	1.34
74HCT645	1.11
74HCT646	2.40
74HCT648	1.90
74HCT651	1.64
74HCT652	0.00
74HCT670	1.10
74HCT673	1.64
74HCT688	1.10
74HCT4002	0.39
74HCT4015	1.13
74HCT4016	0.52
74HCT4017	0.68
74HCT4020	0.74
74HCT4024	0.68
74HCT4040	0.70
74HCT4046	2.10
74HCT4051	0.96
74HCT4052	0.96
74HCT4053	0.84
74HCT4059	2.24
74HCT4060	0.84
74HCT4066	0.66
74HCT4067	4.93
74HCT4075	0.36
74HCT4094	0.84
74HCT4316	0.68
74HCT4351	1.04
74HCT4510	1.54
74HCT4511	0.94
74HCT4514	1.64
74HCT4515	2.50
74HCT4516	1.61
74HCT4520	0.90
74HCT4538	1.02
74HCT7007	0.39
74HCT7046	2.80
74HCT40102	2.43
74HCT40103	1.48
74HCT40104	2.71
74HCT40105	1.82

74HC SERIES SURFACE MOUNT

74HC00M	0.32
74HC02M	0.32
74HC03M	0.32
74HC04M	0.32
74HCU04	0.32
74HC08M	0.32
74HC10M	0.32
74HC14M	0.36
74HC20M	0.36
74HC30M	0.36
74HC32M	0.36
74HC74A	0.36
74HC75M	0.34
74HC85WM	0.65
74HC86M	0.36
74HC123AM	0.46
74HC125M	0.46
74HC132M	0.42
74HC138M	0.38
74HC139M	0.38
74HC154WM	0.64
74HC157M	0.38
74HC161M	0.48
74HC164M	0.48
74HC165M	0.57
74HC173M	0.48
74HC174M	0.38
74HC221AM	0.65
74HC240WM	0.55
74HC244WM	0.55
74HC245AW	0.62
74HC251M	0.42
74HC259M	0.69
74HC273WM	0.55
74HC367WM	0.53
74HC373WM	0.55
74HC374WM	0.55
74HC390M	0.57
74HC393M	0.53
74HC540WM	0.76
74HC541WM	0.76
74HC573WM	1.09
74HC574WM	0.84
74HC688WM	0.84
74HC4017M	0.48
74HC4020M	0.48
74HC4040M	0.44
74HC4046M	1.68
74HC4060M	0.48
74HC4066W	0.84
74HC4538M	0.78

74F SERIES

74F00	0.28
74F02	0.28
74F04	0.28
74F06	0.74
74F07	0.74
74F08	0.28
74F10	0.28
74F11	0.28
74F13	0.62
74F14	0.41
74F20	0.28
74F27	0.28
74F30	0.28
74F32	0.28
74F37	0.41
74F38	0.44
74F40	0.66
74F51	0.44
74F64	0.32
74F74	0.30
74F85	1.46
74F86	0.41
74F109	0.58
74F112	0.72
74F113	1.30
74F114	1.30
74F125	0.60
74F126	0.98
74F132	0.58
74F138	0.58
74F139	0.58
74F148	0.94
74F151	0.58
74F153	0.62
74F157	0.58
74F158	0.70
74F160	1.10
74F160A	1.10
74F161	1.10
74F162	1.28
74F163	1.28
74F164	1.28
74F166	4.32
74F168	4.48
74F169	3.60
74F174	0.76
74F175	0.76
74F181	4.48
74F182	1.80
74F189	4.98
74F190	3.40
74F191	3.20
74F192	3.20
74F193	3.20
74F194	1.48
74F195	2.24
74F219	4.38
74F224	POA
74F240	0.62
74F241	0.62
74F244	0.62
74F245	0.72
74F251	0.62
74F251A	0.66
74F253	0.62
74F257	0.62
74F257A	0.66
74F258	0.62
74F259	POA
74F260	0.78
74F269	7.48
74F273	0.84
74F280	0.68
74F283	0.92
74F299	POA
74F323	POA
74F350	1.50
74F352	0.64
74F353	1.14
74F365	1.28
74F366	1.30
74F367	1.48
74F368	1.30
74F373	0.62
74F374	0.62
74F377	0.92
74F378	1.56
74F381	3.68
74F385	POA
74F395	POA
74F399	0.98
74F412	POA
74F413	POA
74F432	POA
74F521	1.20
74F524	POA
74F533	1.20
74F534	1.20
74F537	1.60
74F538	1.60
74F539	1.60
74F540	1.98
74F541	1.98
74F543	3.98
74F544	POA
74F545	POA
74F547	POA
74F573	2.92
74F574	2.92
74F579	7.98
74F604	4.84
74F620	POA
74F621	POA
74F623	POA
74F646	5.15
74F676	POA
74F821	3.98
74F823	POA
74F825	POA
74F827	4.48
74F841	4.48
74F843	4.93
74F845	POA
74F1244	3.75

74AC SERIES

74AC00	0.38
74AC02	0.49
74AC04	0.40
74AC08	0.40
74AC10	0.40
74AC11	0.40
74AC14	0.40
74AC20	0.40
74AC32	0.40
74AC74	0.48
74AC109	0.64
74AC112	0.81
74AC138	0.65
74AC139	0.65
74AC151	0.68
74AC153	0.65
74AC157	0.81
74AC158	0.65
74AC163	0.80
74AC169	1.98
74AC174	0.65
74AC175	0.80
74AC191	1.38
74AC240	0.92
74AC241	0.92
74AC244	0.92
74AC245	1.10
74AC251	0.60
74AC253	0.60
74AC258	0.60
74AC273	1.10
74AC283	1.40
74AC299	2.06
74AC373	0.94
74AC374	0.92
74AC377	0.98
74AC540	0.98
74AC541	0.98
74AC573	1.38
74AC574	1.38
74AC646	POA
74AC648	POA

74C SERIES

74C00	0.56
74C02	0.56
74C08	0.56
74C10	0.56
74C14	0.56
74C20	0.98
74C30	0.98
74C32	0.68
74C42	2.88
74C48	2.98
74C73	1.28
74C74	0.94
74C76	1.26
74C85	1.86
74C90	1.29
74C93	2.10
74C95	1.60
74C150	5.40
74C151	3.94
74C154	5.82
74C157	3.80
74C164	2.54
74C165	2.54
74C221	2.98
74C240	2.08
74C244	2.08
74C373	2.08
74C374	2.08
74C901	1.18
74C902	1.18
74C903	1.52
74C906	1.10
74C907	1.10
74C908	2.20
74C911	14.42
74C912	14.42
74C914	1.16
74C915	2.74
74C922	6.80
74C923	6.80
74C925	9.30
74C926	9.30
74C929	9.30

74S SERIES

74S00	0.44
74S02	0.44
74S03	0.51
74S04	0.42
74S08	0.42
74S09	0.48
74S10	0.98
74S11	0.48
74S20	0.48
74S32	0.78
74S40	0.25
74S51	0.36
74S64	0.36
74S74	0.98
74S86	1.12
74S112	1.08
74S124	2.42
74S132	0.98
74S133	0.73
74S134	1.95
74S138	0.88
74S139	0.88
74S140	0.78
74S153	1.26
74S157	1.72
74S163	2.60
74S174	0.92
74S175	1.35
74S182	3.29
74S189	2.14
74S195	2.40
74S240	1.00
74S241	1.12
74S244	1.77
74S257	1.22
74S258	1.22
74S260	0.70
74S273	2.44
74S274	2.42
74S280	0.96
74S283	1.90
74S374	2.18
74S394	2.10
74S412	2.10
74S436	2.62
74S437	2.62
74S472	2.32
74S734	2.62

VOLTAGE REGULATORS

78008AP	1.15
7805	0.28
7805A	0.32
7805FA	0.45
7806	0.28
7808	0.28
7809	0.32
7812	0.28
7812A	0.32
7812CTC	0.32
7815	0.28
7818	0.28
7824	0.28
78L05	0.24
78L05A	0.28
78L05ACLP	0.40
78L05ACZ	0.28
78L12	0.28
78L12A	0.28
78L12ACZ	0.30
78L15	0.28
78L24	0.28
78L56	1.10
78M05	0.32
78M05A	0.36
78M12	0.32
78M12A	0.36
78M13A	0.65
78M15	0.32
78S05	0.48
78S12	0.48
78S15	0.55
7905	0.28
7905A	0.32
7905FA	0.60
7909	0.55
7912	0.30
7912A	0.36
7912FA	0.78
7915	0.30
7918	0.30
7924	0.30
79L12A	0.35
79L12ACP	0.35
79M05	0.42
79M05A	0.42
79M05FA	0.65
79M12	0.50
79M12A	0.60
LM317T	0.50
LM317MP	1.06
LM317LZ	0.55
LM338K	4.45
UA78GU1C	1.02
UA79GU1C	1.02
RC4195N	1.80

DIODES

1N2986RB	18.20
1N3881	2.54
1N3997A	6.55
1N4001	0.04
1N4002	0.04
1N4003	0.04
1N4006	0.04
1N4007	0.04
1N4148	0.03
1N4149	0.06
1N4150	0.08
1N4446	0.06
1N4728A	0.24
1N4735A	0.24
1N4736A	0.24
1N4740A	0.24
1N4743A	0.24
1N4744A	0.24
1N4756A	0.24
1N5226B	0.09
1N5232B	0.09
1N5234B	0.09
1N5337B	0.48
1N5349B	0.48
1N5352B	0.48
1N5357B	0.48
1N5365B	0.48
1N5366B	0.48
1N5370B	0.48
1N5380B	0.48
1N5401	0.11
1N5402	0.11
1N6287A	1.55
1N825	1.80
1N825A	1.34
1N827	1.40
1SS252	0.20
5082-2800	0.66
5082-2810	1.40
5082-2835	0.44
AA119	0.60
AA144	0.72
AAZ15	0.58
AAZ17	0.58
AAZ18	0.48
BAV10	0.08
BAV45	4.98
BAW62	0.06
BAX16	0.06
BB204	0.32
BB212	2.48
BB405B	0.22
BB809	0.60
BY179	0.42
BY260-200	3.58
BY261-200	3.98
BYV28-100	0.99
BYV32-50	1.60
CV8805	0.60
DS16C	0.40
MV1404	15.90
MV209	1.20
OA200	0.10
OA202	0.20
OA47	0.14
OA90	0.14
P6KE36A	0.88
P6KE47A	0.88
REC53A	0.40
ZPD2.7V	0.06

ZENER DIODES MISC.

BZY93C7V5	2.66
BZY93C15	2.66
BZY93C18R	2.66
BZY93C20	2.66
BZY93C24V	2.66
BZY93C33R	2.66
BZT03C120	0.40
BZX61C9V2	0.09
BZX61C24V	0.09

ZENER DIODES 400mW
2.4V to 75V
Price: 6p each

ZENER DIODES 500mW
2.4V to 200V
Price: 6p each

ZENER DIODES 1.3 WATT
2.7V to 200V
Price:10p each

ZENER DIODES 3.0 WATT
7.5V to 270V
Price:40p each

ZENER DIODES 5.0 WATT
3.3V to 200V
Price:42p each

ZENER DIODES STUD MOUNT 20 WATT
7.5V to 75V
Price: £4.94 ea.

BRIDGE RECTIFIERS

0.9A/200VDIL	0.38
3.0A/200V SIL	0.57
6A/100V SIL	1.60
8A/200V SIL	1.96
35A/100V Sqr	2.98
KBPC1002	1.64
KBPC3502	2.98
W005- 1A/50V	0.32
W02G- 1.5A	0.40
2W02	0.40
2KBB10R/SIL	0.66
2KBB20R/SIL	0.70
B80C1500/Sq	0.35
B80C1500SIL	0.60
SKB6008/60A	POA

CRYSTALS

HC49(HC18/U)

Freq.MHz	
1.843200	1.60
2.000000	1.66
2.457600	1.49
3.276800	0.98
3.579545	1.10
3.686400	1.02
4.000000	1.02
4.096000	1.10
4.194304	1.10
4.433619	1.10
4.608000	1.10
4.915200	1.20
5.000000/S	1.02
5.068800	1.10
5.242880	1.20
5.888200	1.80
6.000000	1.02
6.144000	1.02
6.400000	1.64
6.552000	1.40
6.553600	1.21
7.372800	0.78
8.000000	1.00
8.867230	1.34
9.830400	1.20
10.00000	1.10
10.69500	1.90
11.00000	1.10
12.00000	0.92
13.87500	2.40
14.00000	1.64
14.31818/S	0.85
14.74560/S	1.10
14.74560	1.10
15.00000/S	1.10
16.00000	1.02
16.00000/S	1.20
18.43200/S	1.10
19.66080/S	1.20
20.00000/S	1.60
22.11840/S	1.68
24.00000/S	1.82
27.64800/S	1.20
30.00000/S	6.99
32.00000/S	1.40
48.00000/S	1.68

S = Series

HC33/U

0.204800	8.23
0.307200	6.99
1.000000	3.95
1.843200	3.71
2.000000	4.65
2.097152	3.71
2.457600	1.92
2.500000	1.92
3.000000	2.25

HC49/U4H

3.276800	1.66
3.579545	1.58
5.068800	2.25
7.864320	1.49
8.000000	1.14
10.00000	2.25
11.05920	2.40
12.00000	1.14
14.00000	2.25
16.00000	1.14
20.00000	1.52
24.00000	1.90

UM-1

8.000000	2.25
8.192000	2.02
10.00000	2.25
11.00000	2.25
12.28800	2.66
15.00000	2.25
17.73447	2.80
18.00000	2.50
20.00000	2.25
21.00000	2.25
24.00000	2.80

CRYSTALS MISC.

HC43/T 1.000000	6.99
MINI CYLINDER 0.032768	0.88
WATCH 0.032768	0.82

CRYSTAL OSC. MODULES

8pin DIL Plastic pkg TTL Output
4 Pins spaced at corners of 8pinDIL

Freq.= MHz
4, 4.9152, 8, 10, 12, 16 & 20
Price: £2.98 ea.

24, 32, 40 & 50MHz
Price £3.40 ea.

8pin DIL Sealed Metal Package HCMOS Output

13.2mm sq.
Pins spaced at corners of 8pinDIL
Freq.= MHz
3.6864,4,8,10,12,16, 20,24,32,40 & 50
Price: £4.20 each

TTL Output
14pin DIL Layout
Sealed Metal 4pin Pkg
Freq.= MHz
1MHz **£8.90 ea.**

4,4.9152,6,8,9.8304, 10,12,15,16, 18.432, 19.6608, 20, 24, 25 & 30MHz
Price: £3.52 ea.

30, 32, 32.768, 33.33, 40 & 50MHz
Price: £4.45 ea.

Programmable Crystal Oscillators

EXO-3C SERIES
8pin DIL Plastic Package
Freq.= MHz
12, 14.31818, 16, 16.384,19.6608 & 20MHz
Price: £3.92 ea.

16pin DIL Plastic Package
Programmable for 57 Diff.Frequency

SPG8640AN
0.005 to 600kHz

SPG8640BN
0.0083 to 1MHz

SPG8640CN
0.064 to 768kHz

SPG8650BN
0.00083 to 100kHz

Price: £ 9.25 ea.

DC to DC Converters

TDK CE-0344	5.60
3W5R 15-15	27.50
IPL S.010	23.40

1 Watt DC/DC 5V input ±Output DIL & SIL by Newport
NMA0505±5V
NMA0509±9V
NMA0512±12V
NMA0515±15V
Price:£7.90ea.

DC/DC Converters by Computer Products

PM623	24.60
PM671	26.70
PM672	26.70
PM903	44.00
PM951	46.50

RESISTORS

METAL FILM 0.25W 1%
E24 Series
10R to 1M 3p each
N.B. Min Qty. Order
Min. 5pcs per value

METAL FILM PRECISION 0.25 WATT 0.1%
E96 Series
100R to 255K
Price: £0.94 each

HIGH PRECISION NON-INDUCTIVE WIRE WOUND 0.15 WATT 0.1%

Temp.Coeff.3ppm
10R,50R,100R,250R, 10K,100K
Price: £3.85 each

HIGH PRECISION NON-INDUCTIVE WIRE WOUND 0.33 WATT 0.1%

Temp.Coeff.3ppm
1R,5R,10R,20R,50R
Price: £3.60 each

100R,120R, 250R, 500R,1K, 2K, 5K, 10K,20K
Price: £3.10 each

MEMORIES

DYNAMIC RAM

4164-10	1.40
4164-12	1.20
4164-15	1.20
41256-8	2.40
41256-10	2.40
41256-12	2.40
41264-15	2.24
41464-12	4.45
41464-10	4.45
4464-10	2.80
414256A-70	3.90
44C256AZ-10	6.95
44C256-8	5.00
511000-85	8.45
HM48416AP-15	4.60
HM48416AP-20	4.25
HY53C256LS-80	1.60
HY53C464LS-80	3.95
HYB511000-85	8.45
KM44C256AZ-10	6.95
M5M4464P-15	4.60
MK4116N-54	2.80
MK4564N-15	1.20
NMC3764N-15	1.60
UPD41464C-12	4.20
UPD41464C-15	4.20
UPD416C-2	3.40
UPD416C-3	3.65
UPD446D-1	2.60

STATIC RAM

2114-3L	3.40
6264LP-10	2.40
6264LP-12	2.40
62256LP-12	4.95
62256LP-10	4.95
CDM6116AE3	5.30
CDM6117AE3	5.85
HM1-6116-5	4.38
HM3-6116-5	3.60
HM6116LP-2	2.60
HM6116LP-3	2.60
HM6117LP-3	5.75
HM62256LP-10	7.93
HM6264ALP-12	3.95
HM6264ASP-20	3.95
HM6267P-35	5.07
HM628128LP-80	18.55
HM66204L-12	15.80
KM62256ALP-10	4.95
LH5164D-10L	2.40
P2114AL-2	3.40
P2114AL-4	3.40
PCD5101P	3.30
UPD43256AGU10L	8.33
UPD43256C-12	5.60
UPD4364C-15	4.70

UVPROMS

27C128-25	3.95
27C64A-15	3.95
27C256-15	3.95
27C256-25	3.95
D27256	5.40
27C512D-12	6.48
27C1000D-12	8.92
27C4096-12	POA
HM27C101G-20	9.80
HN27C1024HG10	16.63
HN27C64FP-20T	3.40
HN27C64G-15	4.20
HN27C64G-20	4.20
HN462532P	4.50
HN4827128G-25	4.55
HN482764G	3.80
M2716-1F1	3.50
M5L2732K	4.40
M5L2764K	3.30
MBM27C64-20/21V	4.90
MBM27C128-30	4.20
MBM27C256-30	5.10
NMC27C256Q-25	4.95
NMC27C64Q-25	3.66
TMS2516JL-45	4.58
TMS27128JL-25	4.60
TMS2716JL-45	4.60
UPD27256D/21V	5.60
UPD2732A/21V	4.95
UPD27C256D-15	5.80
UPD27C512D-15	6.96
UPD27C64D-25	4.95

EEPROMS

28C64-25	9.80
28C64-15	10.95
28C256-20	25.84
28C256-15	27.50
28C256-15DC	28.50
X2816AD	5.10
X2816AP-25	5.10
X2864AP-35	12.20
24C01	1.62
24C02	2.10
24C04	2.98
24C16	5.40
28C04A-20	4.40
59C11	1.44
93C06	1.12
93C46	1.28

MISC. MEMORIES

6341-1J	4.58
AM2148-45DC	5.44
AM27S281PC	3.98
IDT7130LA-100P	POA
IDT7132LA-100P	POA
MB8414E	4.95
MCM4027AC3	2.80
N82S126AN	2.49
N82S153N	5.80
N82S181AN	6.09
NMC6504J-9	3.40
NMC9306N	1.45
P5101L-1	3.90
TBP18S030N	1.74
TBP24S10N	2.90
TBP24SA10N	3.15
TC5501P	3.50
TC5504AP-2	3.40
TC5516PL-15	4.20
TC5517AP-2	4.20
TC5565PL-15	3.60
TMS4014JDL	3.40

CAPACITORS SURFACE MOUNT

Multilayer Ceramic
63 VOLT
Case Size: 1206
L2xW1.25mm

10pF 22pF 33pF 47pF
100pF 220pF 330pF
470pF 1000pF 2200pf
3300pF 4700pF
10000,
22000pF 33000pF
Price: 15p each

47000pF 100000pF
Price: 18p each

MICROPROCESSOR & SUPPORT ICs

100114DEC	7.40
100141DC	9.80
6303XP	8.76
6321P	4.20
63485CP32/sm	19.95
63B03XP	10.07
6502	3.98
6502A	5.40
6520P	4.40
6522	4.40
6522A	5.26
6551	4.43
6551A	4.43
65C02P2	5.84
65C02P3	6.98
65C102P2	7.00
65C22P2	4.80
65C51E-1	3.80
65C51E-2	4.38
68000P-10	6.98
68000P-16	18.20
68000P-8	6.50
68008P-8	7.85
68010P-12	POA
6802P	3.40
6803AP	POA
6805E3E	10.98
6810P	POA
6821P	1.52
6840P	3.40
6844P	17.20
6845P	4.86
6845SP	5.40
68A00P	POA
68A09P	4.30
68A21P	1.98
68A40P	2.56
68A50P	2.98
68B09P	3.98
68B21P	1.98
68B40P	2.98
8080A	4.96
8085AH-2	5.98
8086	3.40
8086-2	3.90
80C286-12/pga	48.50
80C286-8/plcc	24.40
80C85A	4.95
80C85A-2	5.94
8118-5CH	7.60
93L34DC	7.08
AM25LS2568P	2.68
AM25LS2569P	2.68
AM2602PC	2.30
AM26LS31DC	2.30
AM26LS31PC	1.26
AM27S191ADC	10.20
AM27S281PC	6.25
AM2964BDC	12.36
AM2965DC	6.36
AM2966PC	3.98
AM29826DC	3.34
AM685DL	9.82
AM8238PC	5.60
AM9050CDC	4.95
AM9050CPC	4.60
AM9102CPC	2.82
AM9114BDM	9.96
AM9551PC	9.66
AM96L02PC	3.35
AY-5-8136	6.45
AY-5-8136-006	6.45
C1164/SMD	4.98
C8231A	59.00
C8253	3.60
CA80C85B	5.98
CD82C85	9.62
CD82C86H-5	9.74
CG80C286-12	48.50
CG80C286-16	65.00
COM8136	6.45
COM81C17	8.15
CP82C54	6.42
CRT-8004-001	9.65
CS8205	8.92
D3232	5.60
D8086	5.48
D8086-2	8.80
D8202A	POA
D8254-2	6.42
D8284A	3.90
D8288	6.48
D82C284-12	9.60
D82C284-8	7.85
D82C288-10	10.96
D82C288-12	11.85
D82C288-8	9.36
D8748H	9.95
DM9601N	2.45
DP8228N	6.36
DP8238N	6.36
DP8304BN	2.34
DP8311N	6.54
DS1221	6.44
DS1231-20	4.44
DS1232	3.26
DS3486N	3.20
DS3487N	3.20
DS34C86N	4.80
DS34C87N	4.80
DS3631N	3.33
DS3632N	2.81
DS3633N	3.33
DS3634N	2.81
DS3691N	4.96
DS3862N	7.38
DS5000-32-12	47.50
DS8640N	1.20
DS8820AN	2.95
DS8832N	2.68
DS8836N	2.44
DS8837N	2.40
DS8838N	2.40
EF6803A-1P	3.80
EF6803P	3.80
EF6821P	1.30
EF68B09P	3.18
EF68B21P	1.44
EP610PC-35	POA

HD1-0165-5	10.96
HD146818AP	4.20
HD3-6402-9	6.16
HD3-6440-9	8.89
HD3-6495-9	8.89
HD44883	9.52
HD46505SP	9.85
HD46802P	5.50
HD6321P	4.20
HD63485PS32	32.50
HD63B03XP	11.95
HD68000-8	11.59
HD6845SP	6.92
HD68A52P	5.60
HD68B21P	4.29
HI3-7159-5	20.98
HI3-7159A-5	23.40
HM10422	14.30
ID82C86H	17.06
IM6402AIPL	10.20
IM6402IPL	7.75
IM6403IPL	10.80
IMS2600P-15	4.40
INS8250N	7.80
INS8250N-B	7.80
M5M82C51AP	4.20
M5M82C54P-6	5.40
MAB8031AH12P	4.56
MAB8035HL-6P	5.98
MC10103P	1.98
MC10115L	3.21
MC10115P	1.98
MC146805E2P	9.18
MC68000P12/16	POA
MC68010P10/12	POA
MC6802P	2.47
MC6809P	6.78
MC6821P	1.80
MC6840P	5.05
MC6844P	18.40
MC6845P	7.38
MC6850P	3.35
MC68705R3P	25.35
MC68A00P	7.02
MC68A09P	7.62
MC8314P	6.60
MCM6810P	3.00
MCM68A10P	5.35
MM53200N	3.40
MM58167BN	10.64
MM58174AN	14.80
MM58274CN	9.18
MSM5832RS	3.39
MSM80C35RS	4.90
MSM80C39/SMD	6.45
MSM80C85A	3.95
MSM80C85A-2	5.98
MSM80C86	7.60
MSM81C55	4.60
MSM82C51A	3.58
MSM82C53-2	3.98
MSM82C53-5	3.58
MSM82C54-2	4.20
MSM82C59A-2	3.98
MSM82C84A	3.30
MSM82C84A-2	3.60
MSM82C88	12.60
N80C286-10/pl	24.50
N80C286-12/pl	29.54
N80L286-8C2/pl	36.20
N8235N	3.68
N8264N	3.68
N82S126AN	3.25
N82S181F	10.04
NS16450N	4.68
NS16550AFN	12.60
NSC800N-1	10.80
P8032AH	4.29
P8051AH	11.20
P8052AH/Basic	23.45
P8080A	3.90
P8085A-2	5.98
P8085AH-2	5.98
P8088	4.80
P80C31BH	4.54
P80C86AL-2	12.60
P8155H/2	6.98
P8185	18.10
P8205	2.00
P8212	2.40
P8226	2.40
P8251A	3.90
P8253	2.80
P8255A-5	3.90
P8259	2.85
P8259A	3.20
P8274	9.98
P8279-5	3.20
P8282	2.64
P8286	3.60
P82C54	4.10
P82C54-2	4.80
PAL10L8CN	1.90
PAL12H6CN	1.90
PAL16R4BCN	2.17
PAL20L10CNS	4.35
PAL20X8CNS	3.32
PALC16L8Q-25CQ	6.10
PALC20L8Z-45CQS	5.17
PALC22V10H-35QS	8.34
PCD8584P	8.28
PCF8566P	8.28
PCF8566T	8.28
PCF8570P	7.85
PCF8573P	6.72
PCF8574P	5.90
PCF8574T	5.90
PCF8591P	9.35
R6502AP	5.70
R6520P	4.40
R6522	4.40
R6522AP	5.80
R65C02P2	5.84
R65C02P3	6.90
R65C02P4	8.95
R65C102P2	6.85
R65C21P2	5.94
R65C22P2	4.80
SAB80C32P	5.95

SAB8155-P	3.82
SAB8259AP	3.59
SAB82C54-2-P	4.12
SAB82C55A-2-P	4.80
SC80C451ccn64	13.60
SCN2661bc1n28	3.35
SCN2661ccn28	3.35
PAL16R4-15CN	2.98
TL16C552FN	12.58
TMP7002NL-2	4.97
TMP8085AP-2	5.98
TMS3477NL	6.68
TMS3700NSB	8.78
TMS3702ANS	8.78
TMS3835ANS	7.55
TMS77C01NL	10.74
TMS9900NL	24.40
TMS9901NL	14.16
TMS9902ANL	15.94
TMS9914ANL	23.10
TMS9928ANL	7.40
TMS9995JDL	69.85
UA9636ACP	1.98
UA9637A	1.98
UA9638CP	1.98
UA9639CP	1.98
UM6845B	4.95
UM9151	POA
UM9151-3	POA
UPB8238	POA
UPB8282C	4.98
UPB8284AD	4.98
UPB8286C	4.98
UPD70108C-10	9.10
UPD70108C-8	6.95
UPD70116C-10	12.90
UPD70116C-8	9.20
UPD71055C	4.38
UPD7201AC	11.68
UPD7201C	6.80
UPD765AC	5.42
UPD765AC	5.42
UPD780C-1	4.76
UPD80C39HC	8.42
UPD8155HD	5.84
UPD8251AFC	4.08
UPD8253C-2	3.32
UPD8253C-5	3.32
UPD8286C	POA
UPD8741AD	12.52
UPD8749HC	13.98
V20-10MHz	9.10
V20-8MHz	6.95
V30-10MHz	12.90
V30-8MHz	9.20
V61C30P	7.80
VC0106N6	8.60
Z0800110PSC	16.90
Z0868112PSC	3.20
Z180-MPU	POA
Z8001B-CPU	11.96
Z8018008VSC	8.25
Z80A-CPU	1.25
Z80A-CTC	1.98
Z80A-DART	3.15
Z80A-DMA	3.95
Z80A-PIO	1.25
Z80A-SIO/0	3.40
Z80B-CPU	1.52
Z80B-CTC	3.00
Z80B-DART	5.80
Z80B-DMA	POA
Z80B-PIO	2.20
Z80B-SIO	4.50
Z80C00AB6	2.98

TELECOM & SPECIAL FUNCTION ICs

62X0890-U18	3.70
707W02020	5.25
733W00124	5.25
AMA1503GXB	4.68
BAA1505	1.80
CLA25106/PLCC	5.95
GA05001GDB	3.20
KS-49258/PLCC	5.92
MJ1454BB	7.65
MK5175N	3.80
OC-147-7	2.40
PBD352303	4.35
PP34C108	6.80
Q4704	3.60
QMV16BP5	7.98
QMV18C	6.95
QMV18CN1	7.85
QMV18CW1	7.85
QMV25C	8.42
QMV62AW1	6.90
S4534-AMI	4.20
SA336931	2.95
SAA5025D	5.40
SCM66115P	3.40
SGS7P050	4.55
SP1450B	5.76
ULA1RB029E1	6.80
ULA20RK008E1	59.72
XR-T5683	3.60
ZNA2L029J-BS	3.80
ZNPCM1J-BS	8.95

OPTO ELECTRONICS

4N25	0.60
4N26	0.60
4N33	0.40
4N38	0.56
6N139	1.60
CNX36	0.38
CNY17-3	0.64
CNY21N	POA
DF08	0.40
HCPL-2200	5.98
HCPL-2231	5.98
HCPL-2602	5.68
HCPL-2630	3.68
HCPL-2730	3.45
HCPL-2731	3.20
HCPL-4200	5.98
ILD74	1.44
ILQ1	1.60
ILQ74	2.25
ISQ74	2.25

TIL100	1.98
TIL111	0.60
TIL113	0.60
TIL117	0.85
TIL119	1.20
TIL311	9.65
TLP504A	1.58
TLP521-4GB	4.20
TORX173	4.96
TOTX173	4.96

LINEAR & MISCS.

3630BM/BB	3.40
49620/BB	POA
555-TIMER	0.20
6341-1J	POA
741-OPAMP	0.18
AD0P07CN	2.14
AD520JN	POA
AD524	21.52
AD534JH	POA
AD537JH	POA
AD548JN	1.80
AD578JN	POA
AD581JH	8.92
AD581KCSA/SMD	9.97
AD585AQ	POA
AD592CN	POA
AD594AD	12.64
AD595AD	10.20
AD648JN	3.40
AD707JN	3.40
AD711JN	2.34
AD712JN	3.72
AD7245JN/KN	POA
AD741KN	3.69
AD7523KN	9.80
AD7537JN	32.98
AD7537LN	POA
AD7542KN	POA
AD7543JCWE	POA
AD7578KN	46.15
AD844AN	8.75
ADC0804LCN	4.20
ADC0820CCN	22.40
ADC0834CCN	10.80
ADC804LCWM	12.10
ADC84KG-10	12.66
ADC908HP	18.42
ADDAC80N	POA
ADG201AKN	4.86
ADOP07CN	2.32
AH0015CD	17.20
AY-3-1270	3.60
AY-5-1013	3.20
AY-5-1013A	5.24
AY-3-1015D	3.60
AY-5-1250	POA
AY-5-3600-PRO	9.96
BA6109	1.68
BA6208	1.40
CA3046	0.51
CA3046(SMD)	0.89
CA3054	0.94
CA3059	1.20
CA3078AT	2.42
CA3079	0.88
CA3080E	0.70
CA3081	0.96
CA3089E	1.22
CA3094AE	2.16
CA3096AE	3.48
CA3096CE	1.82
CA3097E	2.60
CA3120E	POA
CA3130BT	19.20
CA3130E	1.10
CA3140AE	1.34
CA3140E	0.44
CA3146E	0.90
CA3160E	1.25
CA3240E	0.98
CA3240E1	2.16
CA324E	0.98
CA3260E	1.68
CA3280AE	5.94
CA3280E	3.42
CA555CE	0.20
CA741CE	0.18
CS5503-KD	POA
CX7925B	POA
D169CJ	POA
DAC0800LCN	4.10
DAC0832LCN	10.67
DAC08CP	2.60
DAC08EP	3.64
DAC1008LCN	10.73
DAC1222LCN	20.40
DG201ABK	3.83
DG211	1.56
DG508ACJ	3.98
DG508CJ	3.25
DS1488N	0.36
DS14C88M/SMD	1.65
DS14C88N	1.65
DS14C89AN	1.65
HA12017	1.44
HA13426	11.96
HA17723	1.10
HD75189P	POA
HEF4754V	22.20
HI1-0201-5	3.60
HI1-508A-5	11.21
HI1-549-5	POA
HI1-574AKD-5	42.50
HI3-0201-5	3.20
HI3-0509A-5	7.15
HI3-201-5	3.20
HIIL1	POA
HS574-AK	18.20
ICL7104-16CPL	26.08
ICL7107CQH/PLCC	5.20
ICL7109CPL	9.85
ICL7116CPL	6.74
ICL7117CPL	6.74
ICL7126CPL	6.74
ICL7135CPI	8.98
ICL7136CPL	6.94
ICL7137CPL	6.94
ICL7606CJN	12.24

ICL7611DCPA	1.32
ICL7621DCPA	1.98
ICL7622	POA
ICL7650CPD	4.98
ICL7650SCPD	6.27
ICL7652BCPD	8.24
ICL7652CPD	8.24
ICL7660CPA	1.40
ICL7660SCPA	3.80
ICL7662CPA	4.40
ICL7663BCJA	6.78
ICL7663BCPA	5.10
ICL7664CPA	7.95
ICL7665ACPA	4.98
ICL7673CPA	1.38
ICL8052ACPD	8.73
ICL8068AJD	11.38
ICL8069CCSQ	3.75
ICL8069DCSQ	2.88
ICL8069DCZR	2.88
ICL8211CPA	2.56
ICL8212CPA	2.48
ICM7170IPG	6.42
ICM7207AIPD	6.42
ICM7207IPD	6.42
ICM7209IPA	3.75
ICM7211AMIPL	4.68
ICM7211MIPL	4.68
ICM7212AMIPL	3.88
ICM7213IPD	4.58
ICM7216AIJI	22.44
ICM7217AIPI	9.20
ICM7217BIJI	10.42
ICM7217IJI	10.42
ICM7218AIJI	6.85
ICM7218AIPI	6.85
ICM7218DIJI	6.85
ICM7218EIJL	14.76
ICM7224IPL	8.98
ICM7226AIJL	26.12
ICM7226BIPL	23.54
ICM7249IDM	POA
ICM7555IBA	2.40
ICM7555IPA	0.84
ICM7556IPD	1.85
IM6403IPL	10.80
L272	2.10
L272M	2.10
L293E	3.90
L297A	4.69
L4805CV	2.20
L487	3.15
L4960	3.15
L702B	2.94
LA6250	POA
LA6358	POA
LA6510	POA
LA6520	POA
LC7132	POA
LC7522	POA
LC7555	POA
LD111ACJ	POA
LF13508D	18.20
LF311H	10.80
LF347N	2.40
LF351N	0.98
LF353N	0.86
LF355N	1.82
LF356N	1.82
LF357BN	4.98
LF357M/SMD	4.98
LF357N	1.20
LF398N	3.98
LF411CN	1.48
LF412CN	1.98
LF441CN	0.75
LF442CN	0.99
LF444CN	2.71
LH0002CN	10.80
LH0032CG	33.60
LM101AH	5.65
LM10CN	9.24
LM111H	6.74
LM13600N	3.40
LM13700N	3.40
LM1391N	3.40
LM139J	6.60
LM1458N	0.82
LM1496N	2.95
LM1801N	7.92
LM1881N	4.80
LM1889N	7.40
LM1894N	4.16
LM218H	15.75
LM239N	3.90
LM2901N	1.25
LM2903N	1.25
LM2904N	1.25
LM2917N-14	6.10
LM2917N-8	5.80
LM294OCT15	2.95
LM294OCT5	2.50
LM2984CT	7.50
LM301AN	0.36
LM307N	1.39
LM308N	1.65
LM310N	2.98
LM311N	0.64
LM311N-14	2.15
LM312H	8.95
LM317AT	2.60
LM317T	0.52
LM317T-SGS	0.52
LM318N	2.98
LM319N	2.84
LM320LZ-12	0.34
LM324AN	3.66
LM324J	2.47
LM324N	0.64
LM325N	9.40
LM3301N	2.60
LM334Z	2.20
LM335Z	2.48
LM336Z-2.5	1.48
LM336Z-5.0	1.48
LM337T	1.15
LM339AN	2.98
LM339N	0.60
LM340AT12	1.98
LM340T-5	0.48
LM340T12	0.48
LM340T15	0.30

LM340T5	0.30
LM343H	8.80
LM346N	3.96
LM348DP	0.40
LM348N	0.40
LM350T	6.85
LM351N	2.60
LM358N	0.32
LM359N	4.68
LM360H	7.72
LM361M/SMD	6.40
LM363H-100	16.50
LM369DN	3.82
LM369DRC	3.70
LM380N	1.20
LM381AN	7.88
LM385Z-1.2	2.20
LM385Z-2.5	2.20
LM386M-1/SMD	1.65
LM386N-1	1.40
LM386N-3	1.80
LM386N-4	2.60
LM387AN	5.90
LM388N-1	4.25
LM389N	3.40
LM3900N	1.60
LM3909N	2.64
LM3914N	4.40
LM393N	0.30
LM393P	0.30
LM394CN	5.98
LM3999Z	2.76
LM399H	7.85
LM4250J	11.82
LM555CN	0.28
LM565CN	7.48
LM710CH	2.80
LM723CH	2.80
LM723CN	0.70
LM733CN	2.65
LM741CJ-14	2.20
LM741CN	0.45
LM747CH	2.40
LM747CN	0.90
LM78GCP	2.40
LM79GCP	2.40
LM833N	2.82
LS285AB	2.40
LS288B	3.60
LS7210	4.40
LT1006CNB	2.72
LT1010CT	4.58
LT1028CN8	7.32
LT1032CN	4.70
LT1070CT	9.14
LT1083CP	8.82
LT1086CT	2.90
LTC1052	7.97
LTC485CN8	2.16
LTC490	4.40
M5218AL	POA
M5220	POA
M5238L	POA
M5298P	POA
M706B1	1.25
MAX1232CNG	POA
MAX1232CPA	3.57
MAX1259CPE	POA
MAX162ACNG	POA
MAX232ACPE	4.84
MAX232CPE	2.80
MAX232EWE	3.80
MAX232N	2.80
MAX280CPA	6.94
MAX452CPA	5.38
MAX627CPA	2.98
MAX660CPA	5.72
MAX690ACPA	6.58
MAX694CPA	POA
MAX697CPE	POA
MAX7219CNG	7.15
MAX8211CPA	2.28
MAX901BCPE	POA
MC1377P	4.93
MC1413P	0.74
MC14411P	11.38
MC14416L	17.60
MC14495P	4.82
MC145406P	2.10
MC1455P	0.40
MC1455P1	0.60
MC1458P	0.32
MC1488L	2.40
MC1488P	0.38
MC1489A	0.80
MC1489AL	2.25
MC1489AN	0.80
MC1489L	2.20
MC1489P	0.38
MC1496N	2.20
MC1558L	3.32
MC1648P	12.40
MC1658P	12.78
MC1709CPI	1.20
MC1723CP	1.20
MC1741CP	0.45
MC3242AP	7.54
MC3301P	0.88
MC3302P	0.60
MC3340P	1.60
MC3357P	3.20
MC3403P	1.40
MC3446AP	6.75
MC3479P	7.92
MC3523U	5.80
MC4024P	12.78
MCT2	0.84
MCT61	1.18
MF10CCN	8.95
ML924	4.90
MM5309N	5.76
MM53105N	4.98
MM80C95N	1.44
MP7570JD	POA
MUX24EQ	9.60
MUX24FP	9.60
MV500DP	3.05
MV601DP	3.36
MV8870DP	5.52
NE5020N	10.84
NE527N	3.71
NE532N	0.60

NE536H	4.90
NE5530N	3.82
NE5532AN	1.58
NE5532N	0.80
NE5534AN	1.80
NE555N	0.20
NE556/SMD	0.70
NE556N	0.38
NE558N	2.28
NE564N	3.42
NE565N	2.94
NE567N	0.65
NE568N	POA
NE570N	4.60
NE571N	3.40
NE589N	4.25
NE592/SMD	1.80
NE592N	1.40
NE592N14	0.92
NE602AN	2.98
NE602N	2.40
NE604AN	8.24
NE605N	8.60
NE612AN	2.87
NJM4556D	1.20
NJM4558DX	1.20
OP07CJ	3.60
OP07CN	0.95
OP07CP	0.95
OP07EP	3.10
OP11GP	5.85
OP177FP	3.71
OP27GP	2.89
OP42FZ	7.44
OP77GP	2.07
OPO7CN	0.95
PM7548HP	18.20
RC4136N	0.98
RC4193N	POA
RC4194N	2.85
RC4207GN	1.92
RC4558	0.90
RC4558P	0.60
REF01CP	3.33
REF01HP	3.33
REF02CP	3.98
REF03GP	3.69
REF25Z	1.12
S2560A	POA
SAA1027	6.51
SAA1043P	7.98
SAA3049P	9.92
SAA5025D	7.65
SAA6002A	10.80
SAS560S	3.40
SED2000FVA	9.60
SFC2301ADC	6.78
SFC2741DC	0.18
SG3524N	4.60
SI7660CJ	1.92
SL1452	6.75
SL2364C	3.97
SL3117B	POA
SL486DP	2.98
SL490DP	2.80
SL560CDP	3.00
SL6270CDP	3.30
SL6700CDP	5.47
SN5281CN	POA
SN55451BJG	POA
SOC12	0.20
SP1648DG	5.53
SP4534	POA
SP4740DP	4.46
SP8629DP	3.44
SP8660DP	4.96
TA7215P	7.20
TA7256P	2.60
TA7368P	POA
TA7658P	POA
TA78005AP	POA
TA8200AH	POA
TA8410K	2.80
TA8449P	POA
TA8659AN	POA
TAA861A	POA
TBA120S	0.60
TBA240B	POA
TBA570	POA
TBA820MT	POA
TBA920	POA
TBA990	POA
TC9106BP	POA
TCA335A	POA
TCA965	POA
TCM1520AP	POA
TCM1531P	POA
TCM1705AN	POA
TCM3105N	9.42
TCM5087N	2.40
TCM5089N	2.40
TDA1083	2.60
TDA1085A	2.96
TDA1085C	3.80
TDA1151	1.10
TDA1170S	2.80
TDA1515A	4.98
TDA1521A	4.37
TDA1576	3.90
TDA1578A	3.60
TDA2595	3.32
TDA3048N	1.85
TDA3505	POA
TDA3810	POA
TDA440	POA
TDA4510	3.38
TDA4563	3.38
TDA4660	POA
TDA7010T	POA
TDA7052	2.52
TDA8702	6.22
TEA1045	POA
TEA1060	4.20
TEA5620	POA
TIPC2801KV	8.40
TL026CP	1.84
TL062CN	0.52
TL062CP	0.52
TL064CD	0.98
TL064CN	0.88
TL064ID/SMD	2.10
TL071ACP	1.84

TL071CP	0.64
TL072ACP	1.48
TL072CN	0.50
TL072CP	0.50
TL074ACN	2.85
TL074CN	0.84
TL081CP	0.48
TL082CP	0.48
TL084CN	0.48
TL27L2CD/SMD	1.98
TL497ACN	3.44
TL507CP	4.03
TL7702ACP	2.04
TL7705ACP	2.04
TL7705CP	2.04
TL7709ACP	2.04
TL7770-SC	3.82
TL783CKC	5.10
TLC2201CP	3.74
TLC2274CN	2.85
TLC251CP	2.54
TLC2652CP	4.92
TLC2654CP	4.84
TLC271CP	0.84
TLC272CP	1.30
TLC274CN	2.40
TLC339CN	1.98
TLC372CP	1.40
TLC551CP	3.68
TLC555CP	0.65
TLC556CN	1.58
TLC7524CN	5.24
TLE2061CP	2.20
TLE2062CP	3.40
TLE2064CN	3.45
TLE2161CP	2.42
TMS3477NL	5.96
TPIC2406NE	7.14
TPIC2802KV	8.40
TPIC6259N	3.28
TPIC6273N	3.28
TPIC6595N	3.28
TSC426CPA	POA
TSC500CPE	POA
TSC7106CPL	6.81
TSC7116CPL	5.25
TSC7126CPL	5.35
TSC766OCPA	1.40
U1096B	4.92
U2066B	2.64
U2400B	5.50
U664B	3.95
UA2240PC	1.40
UA709CP	0.85
UA709PC	0.85
UA715HC	4.50
UA723CP	0.70
UA733CJ	2.98
UA741MP	0.60
UA741TC	0.28
UA748CP	0.36
UA748TC	0.52
UA77000UIC	POA
UA798TC	3.80
UCN5800A	2.40
UCN5801A	2.60
UDN2981A	2.00
UDN2982A	2.00
UDN6118A	1.65
UGN3501M	POA
ULN2001AN	0.44
ULN2002A	0.44
ULN2003AN	0.44
ULN2004AN	1.40
ULN2024A	1.40
ULN2032A	1.40
ULN2803AN	0.84
UM5100	POA
UM5101	3.80
XR2211CP	POA
XTR110KP	9.95
Y1112/TI	4.60
ZN1445	POA
ZN414Z	1.04
ZN415E	1.84
ZN423	2.20
ZN425E-8	5.97
ZN426E-8	3.68
ZN428E-8	6.95
ZN429E-8	2.64
ZN449E	4.76

75 SERIES

75107	1.02
75107A	1.02
75108	1.80
75108A	1.84
75108B	2.08
75109A	2.46
75110A	1.36
75113	3.02
75114	3.04
75115	1.60
75116	3.30
75121	2.60
75122	POA
75136	3.10
75138	4.40
75140	2.65
75150	1.60
75150M	2.65
75152	6.36
75154	1.75
75154M	1.75
75155	1.20
75157	4.40
75159	5.45
75160A	5.95
75161A	6.47
75162A	7.59
75172NG	3.68
75173	3.68
75174	3.20
75174NG	3.68
75175	2.60
75176A	1.60
75176B	2.28
75176BT	4.98
75177	2.60
75178	2.60
75182	2.60
75183	2.60
75188	0.40
75189	0.85
75189A	0.85
75361	2.84
75365	2.72
75437A	3.26
75450B	0.64
75451	0.28
75451B	0.48
75452	0.28
75452B	0.48
75453	0.64
75453B	0.64
75454	0.64
75454B	0.98
75462	0.98
75463	1.10
75468	3.60
75469	1.30
75470	POA
75471	1.68
75472	1.48
75473	1.48
75474	2.25
75477	2.10
75491	0.68
75ALS176	2.88
75ALS192	2.88
75ALS193J	3.22
75C1154	2.88
75C1406	2.73
75C185	3.98
75C188	1.20
75C189A	1.32
75C189AD	1.32
75LBC176	2.60

TRANSISTORS THYRISTORS & TRIACS

40406	1.60
40673	2.40
BC107A/B	0.17
BC108A/B/C	0.17
BC109B/C	0.18
BC140-16	0.48
BC146/01	0.58
BC149	0.40
BC157	0.34
BC158	0.34
BC169C	0.14
BC179	0.24

BC182	0.08
BC182A	0.08
BC182B	0.08
BC182L	0.08
BC182LB	0.08
BC183	0.08
BC183C	0.08
BC183L	0.08
BC184	0.08
BC184B	0.08
BC184L	0.08
BC184LC	0.08
BC212-18	0.08
BC212A	0.08
BC212B	0.08
BC212L	0.08
BC212LB	0.08
BC213	0.08
BC213L	0.08
BC214	0.08
BC214L	0.11
BC237	0.08
BC239	0.12
BC307	0.08
BC327	0.08
BC328	0.08
BC337	0.08
BC337-25	0.08
BC489	0.24
BC490	0.30
BC516	0.22
BC517	0.20
BC546	0.05
BC546A	0.05
BC546B	0.05
BC547	0.08
BC547A	0.08
BC547B	0.08
BC547C	0.08
BC548	0.08
BC548B	0.08
BC549	0.08
BC549B	0.08
BC550	0.08
BC550B	0.08
BC550C	0.08
BC556	0.08
BC556A	0.08
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BC557	0.08
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BC558	0.08
BC558A	0.08
BC558B	0.08
BC559A	0.08
BC559B	0.08
BC560A	0.08
BC560C	0.08
BC184C	0.08
BCY71	0.22
BD131	0..88
BD135	0.44
BD241A	0.98
BD242C	0.52
BD243	0.50
BD516	0.78
BD675	0.52
BD676	0.52
BD679	0.54
BD680	0.56
BD743C	1.90
BDT85	1.12
BDX67B	2.78
BDY96	3.60
BF195-C	0.08
BF199	0.22
BF200	0.16
BF256B	0.38
BF256C	0.38
BF259	0.40
BF324	0.28
BF421	0.12
BF450	0.20
BF451	0.22
BF494	0.16
BF759	0.26
BF961	0.66
BF981	0.90
BF982	0.88
BFG65	1.79
BFR53-2GHz	0.48
BFR91-5GHz	0.90
BFR91A-6GHz	1.20

BFW10	1.20
BFX48	0.49
BFX85	0.59
BFX88	0.30
BFX89	1.59
BFY50	0.34
BFY52	0.34
BFY90	0.92
BS107	0.28
BS170	0.38
BS250	0.52
BSR60	0.48
BSX20	0.38
BSX21	0.48
BSX61	1.85
BT136-600	1.10
BUW46	4.94
BUZ11	1.60
BUZ11A	1.62
BUZ47A	6.90
IRFZ14	1.14
IRFZ20	1.77
J113	0.39
J175	0.68
J270	0.92
JA101	0.48
MBD501	1.10
MJE13070	1.10
MJE340	0.68
MJE350	1.10
MJE520	0.80
MPS3638	0.18
MPSA06	0.12
MPSA13	0.12
MPSA63	0.32
MPSA92	0.24
MPSU05	2.21
MTP8P08	2.80
OC147	1.80
OC19	1.85
OC45	0.65
OC72	0.80
OC78	0.80
OC81M	0.80
OC81Z	0.92
PN3643	0.18
TIC106M	0.78
TICP206D	0.61
TICV106D	0.24
TIP115	0.55
TIP121	0.68
TIP145	1.37
TIP2955	0.88
TIP30	0.48
TIP3055	0.88
TIP31A	0.38
TIP32A	0.40
TIP47	0.80
V275LA10	0.92
VN0104N3	0.92
VN66AFD	1.40
VN90AB	2.96
VP0104-N3	0.92
VP0104N2	0.98
VP0104N3	0.92
ZTX212	0.18
ZTX237	0.26
ZTX300	0.18
ZTX313L	0.28
ZTX320	0.38
ZTX510	0.18

IC SOCKETS LOW PROFILE

No. of Pins	Pin spac-ing	Gold Turn Pin	Tin sldr Tail	Gold sldr Tail
6	0.3	18p	6p	18p
8	0.3	18p	6p	18p
14	0.3	31p	8p	31p
16	0.3	33p	10p	33p
18	0.3	39p	11p	39p
20	0.3	45p	12p	45p
22	0.3	54p	14p	
24	0.3	54p	14p	
24	0.6	54p	14p	
28	0.6	60p	16p	
32	0.6	65p	22p	
40	0.6	70p	22p	
48	0.6	85p		
64	0.75	260p		
64	0.9	260p		

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80486SX/DX/DX2	SIS	AMI	128K	32MB	7x16(AT),2x32(VESA)	260 x 220	120.00
80486SX/DX/DX2	SIS	AMI	256K	32MB	7x16(AT),2x32(VESA)	260 x 220	129.00

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80386DX-40MHz	AMD	£75.00
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80486DX-33MHz	INTEL	£245.00
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80287-8	INTEL	£40.00
80287-10	INTEL	£48.00
80287-XL	INTEL	£62.00
80387DX-33MHz	INTEL	£62.00

MEMORIES

SIMM 1Mx9x9 CHIP 70ns	P.O.A.
SIMM 1Mx9x3 CHIP 70ns	P.O.A.
SIMM 4Mx9x9 CHIP 70ns	P.O.A.
SIMM 4Mx9x3 CHIP 70ns	P.O.A.
SIMM 256Kx9 CHIP 8Ons	P.O.A.

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CP-30254	250MB	15msec 3.5" LP	£212.00
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SOFTWARE

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TEAC	FD-235HF	1.44MB 3.5'	£30.00
TEAC	FD-55GFR	1.2MB 5.25"	£35.00
MITSUBISHI	MF355C/258MG	1.44MB 3.5"	£29.00
MITSUBISHI	MF504C/318MP	1.2MB 5.25"	£35.00

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TRIDENT	TVGA 8900CL	New Trident 1MB SVGA	£40.00
TSENG LAB	ET-4000	1MB SVGA	£60.00

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IMSI	SYSTEM MOUSE	3 Button Serial	£10.00
Znix	3 BUTTON MOUSE	MS COMPATIBLE	10.00

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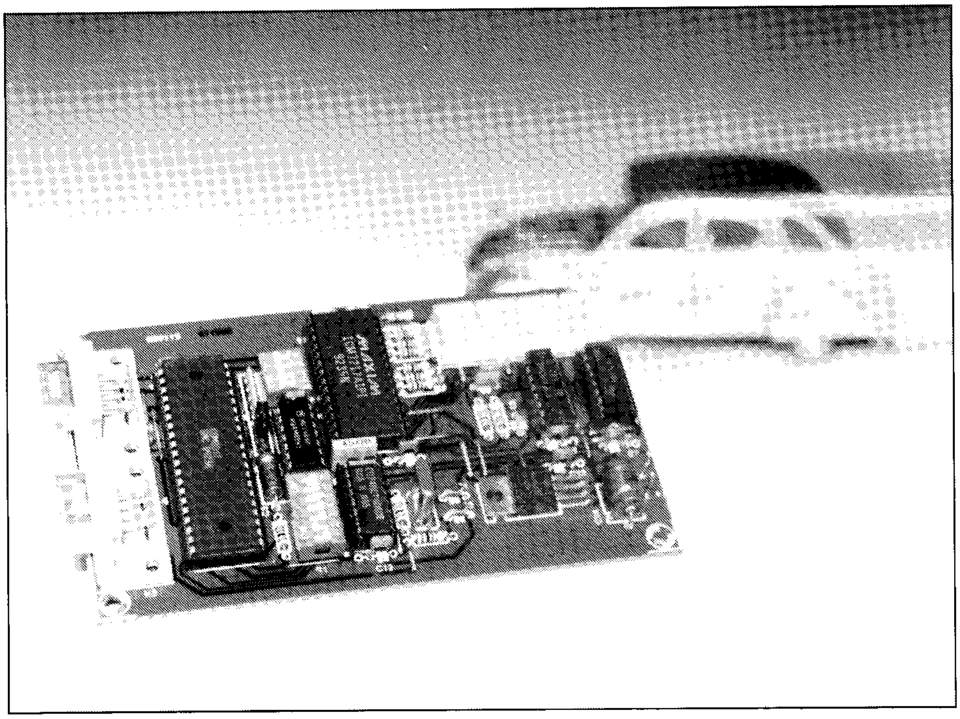
RS232 SPEEDOMETER

Serial ports are frequently used for long-distance communication between computer equipment. The speed at which data is conveyed on such a link is called the baud rate, a figure indicating the number of bits transmitted per second. Unfortunately, in practice there are often gross differences between the programmed and the actually achieved data speed. The circuit described here measures the actual speed of RS232 data.



Design by D. van de Vliet

TWO interfaces may be found on virtually any computer: the parallel Centronics interface, and the serial RS232 interface. These two communication ports allow the computer to exchange data with peripheral devices and/or other computers. The big advantage of the parallel port is the relatively high speed at which data may be transmitted. A single write command to this port is sufficient to transmit eight databits at a time. On the down side, the parallel port requires a large number of wires. Apart from the eight data lines there are at least two control lines, and a ground line. That is 11 lines for a minimum configuration. When the parallel link is relatively long, crosstalk between the individual lines increases, but may be suppressed to some extent by adding a screen around every signal line. All in all, a lot of copper wires are required to set up a reliably operating parallel connection. The parallel port is, therefore, less suitable for long-distance communication.

The second interface is the serial RS232 port, which transmits one bit at a time. In principle, two wires, a signal wire and a ground wire, are sufficient to set up a fast and reliable data connection. A disadvantage of the serial port is that quite a few control signals are required to prevent data being lost. Essentially, two solutions are available to implement handshaking between the sending and the receiving device: hardware (RTS/CTS) and software (XON/XOFF, EOT/ACK, and others). Hardware handshaking is fast but needs a minimum of two extra wires. The software solution does not need extra wires, but slows down the communication because control commands are inserted between the data signals. Fortunately, a serial link with hardware handshaking has fewer wires than a parallel link.

Serial it will be

Once it has been decided to use serial communication between two computer devices, it is necessary to agree on a number of transmission parameters which apply to the transmitter and the receiver. Apart from the transmission speed (baud rate), the error checking method (parity bit) and the number of stop bits have to be made identical at both ends of the serial link. Normally, a start and a stop bit are appended to the eight databits, so that a serial word consists of 10 bits. The parity bit is rarely used these days. In the exceptional case of two stop bits and a parity bit being added, the serial word consists of 12 bits.

Figure 1 shows the structure of 10-bit and 12-bit serial words. The numbers 10 and 12 are essential when determining the effective speed of a serial link. At a baud rate of 1,200, the maximum number of 10-bit words that can be transmitted per second is 120, or 100 if 12-bit words are used.

The baud rate selection depends on a number of factors. If the computer communicates with a peripheral which is located nearby, a high baudrate, for instance, 19.2 kbit/s, may be used. If, on the other hand, a very long cable is used, a lower speed has to be chosen to enable the negative effects of stray capacitance introduced by the cable to be

MAIN SPECIFICATIONS

Baudrate:	300 to 19,200 bits per second
Compatible:	with any RS232 interface
Connection:	inserted into link between equipment
Signal line:	RxD or TxD; selection via jumper
Measurement:	exact data speed
Display:	four 7-segment LED displays
Readout:	datawords per second
Data format:	all existing formats supported

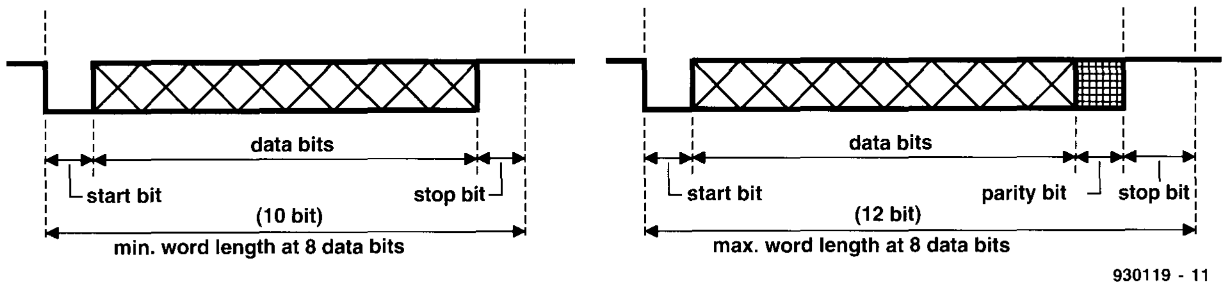


Fig. 1. Structure of 10-bit (left) and 12-bit (right) serial words. Words consist of databits, a start bit, a parity bit, and one or two stop bits.

suppressed.

Note that so far we have only been discussing the actual speed of the interface. By using data compression algorithms, the effective speed of a serial link can be boosted considerably. As a result of compression techniques, each bit conveyed via the cable is given a certain 'added value'.

The exact speed

As already noted, the speed at which a serial link is to operate is determined to a large extent by the baudrate. There are, however, other factors that determine the communication speed. Both at the transmitter and the receiver end of the cable, a microprocessor often needs time to do a lot of calculations before it is able to transmit or receive a byte. Obviously, this is a slowing-down factor, particularly if the calculations are complex, and no buffering is implemented. The delay is caused by the handshaking protocol, which halts the communication for the time needed by the microprocessor to do its number crunching. Consequently, the serial link is much slower than one would expect from the baud rate set on the transmitter and the receiver.

Equipment fitted with data buffers is less affected by delays because the data flow can be maintained while the processor is busy calculating. Unfortunately it is not always evident if such a buffer is present inside a certain peripheral, so that the actual data speed achieved on a data link can only be measured by a special instrument. Such an instrument is described here.

The circuit

The circuit diagram of the RS232 speedometer is given in **Fig. 2**. The heart of the circuit is formed by a UART (universal asynchronous receiver/transmitter), IC$_3$, a type COM8017 or AY3-1015. This IC is capable of converting parallel data into serial, and vice versa. To be able to do this, the UART only requires a clock

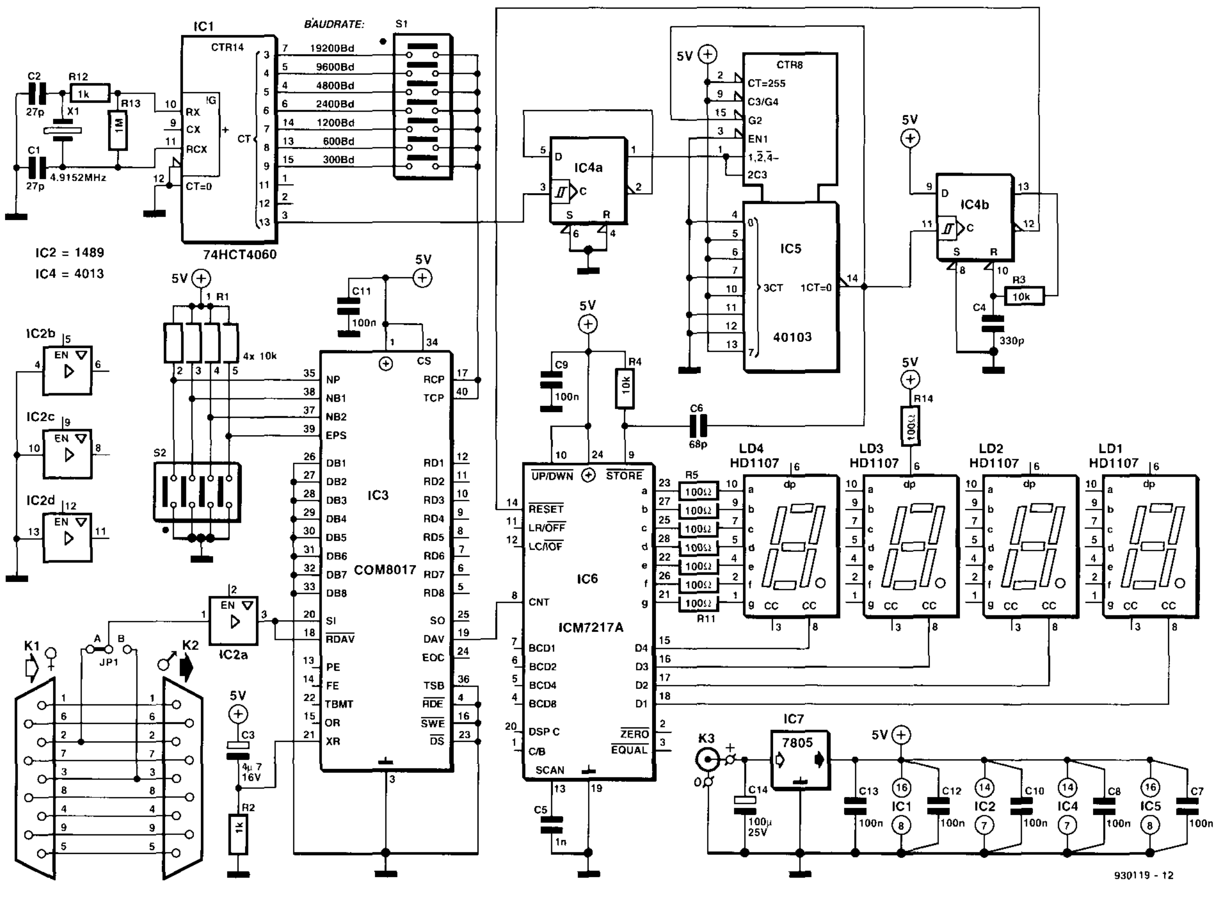


Fig. 2. Circuit diagram of the RS232 speedometer. Most of the work is done by a UART type COM8017.

signal which determines the bit speed. Only a small section of the UART is used in the present circuit. None the less, the approach is economical, since a discrete circuit capable of doing serial-to-parallel conversion with checks on stop bits and parity would be more expensive. The non-used inputs of the UART have been made inactive.

The UART is reset by network R_2-C_3. Behind it sits a display circuit built with a Harris Semiconductor type ICM7217A, IC_6, and four Siemens LED displays type HD1107. Every time the UART receives a valid word, its DAV (data available) output supplies a positive pulse transition (rising edge) which causes the contents of the counter contained in IC_6 to be increased by one. What remains to be done at this stage is to set up a time slot within which the number of DAV pulses is counted. Fortunately, that is not a problem because the circuit contains a baudrate generator which can also be used to create a suitable timing signal for the counter.

The oscillator built around quartz crystal X_1 operates at a frequency of 4.91 MHz. To obtain the desired clock signals, the 4.91-MHz clock is fed to the cascade of divide-by-two ripple counters contained in IC_1.

The desired baudrate is selected with the aid of switches contained in S_1. The UART expects a clock frequency which equals 16 times the baudrate on the serial link. Hence, output Q13 of IC_1 (pin 3) supplies a signal with a frequency of 300 Hz ($4.9152 \text{ MHz}/2^{14}$). The 300-Hz signal is divided by 300 with the aid of a bistable wired as a divide-by-two scaler (IC_{4a}), and a presettable counter (IC_5). The result is a 1-Hz signal at pin 14 of IC_5.

The combination of the counter, the display, and the 1-Hz reference signal allows the number of DAV pulses that occur within one second to be readily measured, so that the exact number of data words conveyed via the serial link in one second is accurately known.

The circuit uses two steps to store the counter information. First, the negative-going edge of the $\overline{\text{STORE}}$ signal (IC_5 pin 14) is used to copy the counter contents into an output register, and from there to the display. Next, a reset signal (IC_{4b}, pin 12) resets the counter in IC_6. Bistable IC_{4b} is wired to operate as a monostable multivibrator (MMV). It generates a reset signal on the positive-going signal edge that appears at the output of IC_5 every second. The mono time of the MMV is determined by network R_3-C_4.

Four bright displays indicate how many bytes (not bits!) reached the receiver during the last second. Usually,

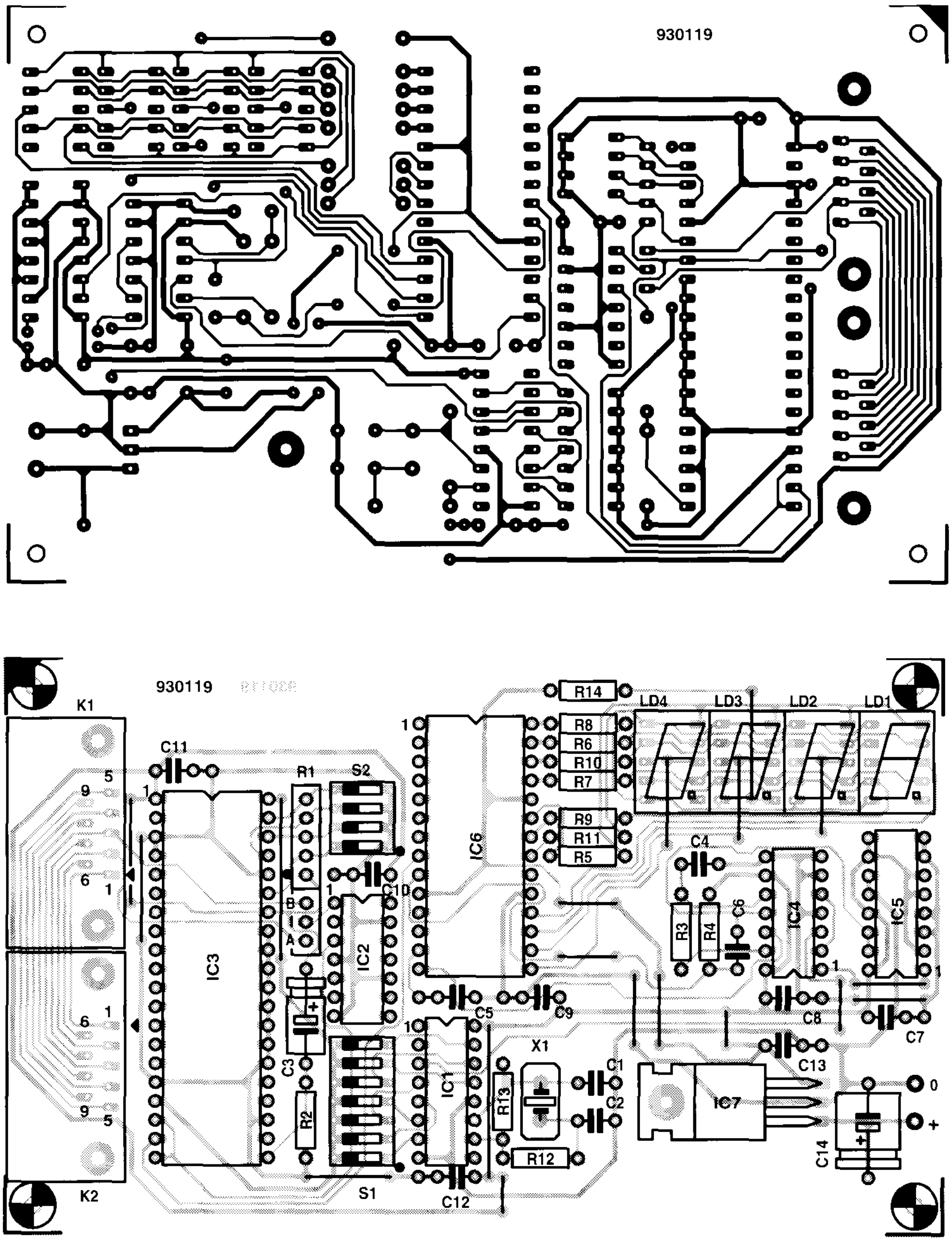


Fig. 3. Artwork of the printed circuit board designed for the RS232 speedometer (PCB not available through the Readers Services).

COMPONENTS LIST

Resistors:
R1 = 4-way SIL array 10kΩ
R2,R12 = 1kΩ
R3,R4 = 10kΩ
R5-R11,R14 = 100Ω
R13 = 1MΩ

Capacitors:
C1,C2 = 27pF
C3 = 4µF7 16V
C4 = 330pF
C5 = 1nF
C6 = 68pF
C7-C13 = 100nF
C14 = 100µF 25V

Semiconductors:
IC1 = 74HCT4060
IC2 = 1489
IC3 = AY-3-1015 or COM 8017
IC4 = 4013
IC5 = 40103
IC6 = ICM7217A
IC7 = 7805
LD1-LD4 = HD1107

Miscellaneous:
K1 = 9-way sub-D socket, angled.
K2 = 9-way sub-D plug, angled.
K3 = mains adaptor socket.
S1 = 7-way DIP-switch.
S2 = 4-way DIP-switch.
X1 = 4.9152MHz crystal.
JP1 = 3-way SIL-header w. jumper

the readout will indicate a value which is at least 10 times smaller than the set baud rate (remember, 10 bits are needed for every word). The advantage of the byte-speed readout is that the user has a clear indication of the amount of information conveyed. The decimal point in LD$_3$ is on continuously to make the displayed value easily readable.

It is important to note that the speed measurement works correctly only if hardware (RTS/CTS, etc.) handshaking is used. Software handshaking uses start and stop commands which are also conveyed via the data lines. Obviously, these commands are recognized as valid databytes by the speedometer, while they are not data proper. Since software handshaking is hardly used any more, you probably need not worry about this deficiency of the speedometer.

The rest of the circuit is really straightforward stuff. The serial input signal is buffered by IC$_{2a}$, a type LM1489. As already mentioned, switch S$_1$ is used to select the desired data speed, while S$_2$ allows you to select the number of stop bits, the parity check, and the number of databits contained in a byte. The function of the two switches is summarized in **Table 1**.

Construction: no problems!

A printed circuit board has been designed to make the construction of the RS232 speedometer as easy as possible. Unfortunately, this printed circuit board is not available ready-made through the Readers Services, so you have to etch it yourself.

It is best to start by fitting the 18 wire links on the board. In this way, the links can not be forgotten later. Also, four wire links are located underneath displays, so they have to be fitted first in any case. It is recommended to use IC sockets since that enables faulty ICs to be replaced more easily.

Fit jumper JP$_1$. Position A means that the speed of the TxD signal is measured, while in position B the speed of the RxD signal is measured. Set the baudrate and the transmission format with the aid of the DIP switches, and the circuit is ready for use.

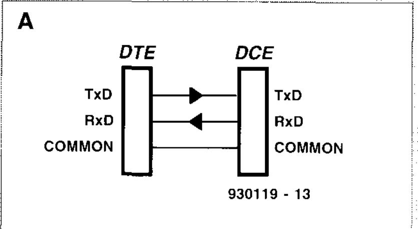
Connect the supply input to the output of a 9V/200 mA mains adapter, and insert the speedometer into the serial link. Next, switch on the speedometer, and start the transmission. The measured value should appear almost instantly on the displays.

■

EVERYTHING UNDER CONTROL?

Wherever data is exchanged via a serial link, it is essential for the transmitter and the receiver to have matching transmission parameters, laid down in the handshaking protocol. The RS232 link supports hardware and software protocols. Software handshaking makes use of extra characters which are added to the data proper. Effectively, one device controls the other by means of the data transmitted. In this way, a computer is capable of sending text line-by-line by adding the 'end-of-text' (EOT) marker at the end of each line. EOT being an ASCII character, the printer is able to interpret this message as a command to print the received data. When it is finished with printing, and ready to receive new data, it transmits an acknowledge message in the form of an ACK code. Like EOT, ACK is a standard ASCII sign.

The advantage of software handshaking is the small number of signal lines that make up the serial link (see **Fig. A**).

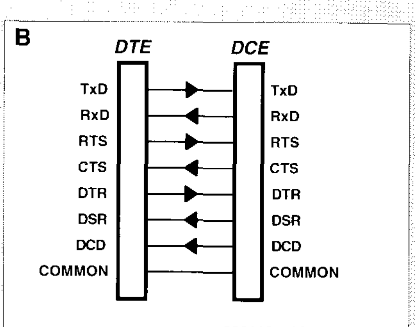


Hardware handshaking is a different kettle of fish, and based on different combinations of handshaking lines. For example, a computer (transmitter or DTE, data terminal equipment) is connected to a modem (receiver or DCE). As soon as the computer is switched on, its DTR (data terminal ready) line (pin 20) becomes active. This is a signal for the modem to become active. In this type of link, the DTR output on the computer is connected to the DTR input on the modem. Hence, the DTR connection on the transmitter is different from that on the receiver.

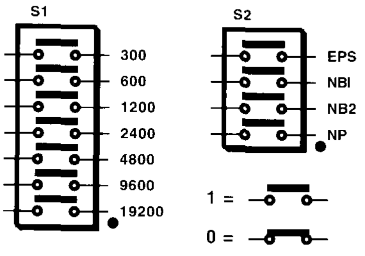
The modem signals that is ready for use by actuating its DSR (data set ready) output (pin 6) on the RS232 port. This signal is detected by the computer on its DSR input. In other words, the modem acts as a transmitter, and the computer as a receiver.

Next, the computer actuates the RTS (request to send) line, pin 4. Via the CTS (clear to send) line, the modem informs the computer whether or not it is ready to accept data. If so, the transmission may commence.

One handshaking line that has not been mentioned so far is called DCD (data carrier detect). It is actuated by the modem, and indicates that a stable connection has been established with another modem via, for instance, the telephone line. By monitoring the status of this line, the computer is able to detect when the carrier disappears from the telephone line.



Evidently, the disadvantage of the hardware handshaking option is the larger number of wires, as shown in **Fig. B**.



settings S2	
EPS = 1	parity = even
EPS = 0	parity = odd
NP = 1	parity = none
NP = 0	parity

NB2	NB1	bit/character
0	0	5
0	1	6
1	0	7
1	1	8

930119 - T1

Table 1. Overview of DIP switch functions.

VIEWDATA RETURNS £6 made by Tandata, includes 1200.75 modem, k/bd, RGB and comp o/p, printer port. No PSU.£6 MAG6P7

IBM PC CASE AND PSU Ideal base for building your own PC. Ex equipment but OK. £14.00 each **REF: MAG14P2**

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PLUG IN ACORN PSU 19v AC 14w , £2.99 REF MAG3P10

POWER SUPPLY fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

ACORN ARCHIMEDES PSU +5v @ 4.4A. on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

GEIGER COUNTER KIT Low cost professional twin tube, complete with PCB and components. £29 REF MAG29P1

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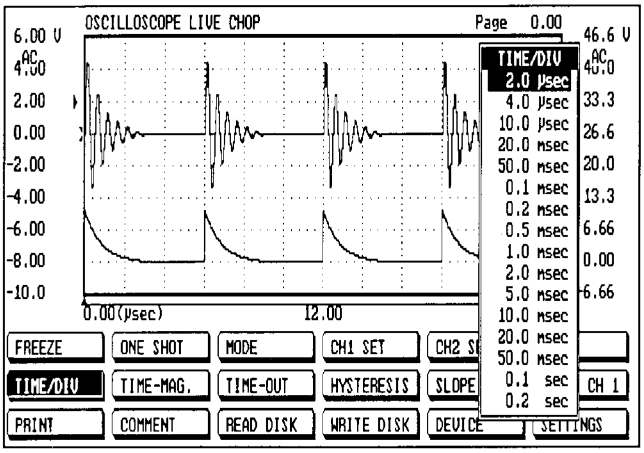

TiePie engineering manufactures a complete range of computer-controlled measuring instruments. Connecting these units to a PC (MS DOS 3.0 or higher) results in a number of comprehensive test instruments:

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Connect the HANDYPROBE to the parallel printer port of the PC and start the software. Measuring can be carried out at once. The HANDYPROBE does not need an external power supply. Some technical parameters:
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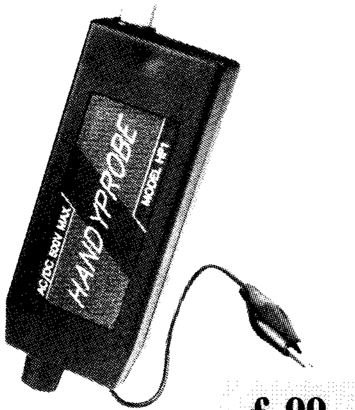

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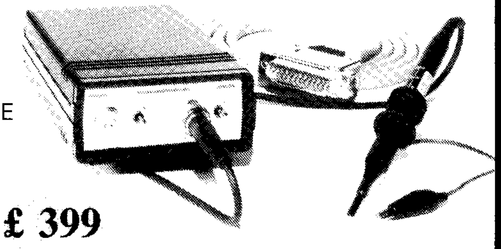
BEST PERFORMANCE: HANDYSCOPE

The HANDYSCOPE is connected to the parallel printer port. This makes it possible to carry out measurements with a laptop or notebook PC. Because of its high resolution (12 bits), the HANDYSCOPE is a very accurate instrument. The measuring rate is 100,000 samples/sec. Either of the two channels can be set independently over a range of 0.5-20 V (with a 1:10 probe up to 200 V). The advanced software enables many measurements to be carried out. Two probes (switchable 1:1-1:10) are provided. The HANDYSCOPE is constructed as a small table model with two BNC connectors.
The length of the cable linking the PC and the HANDYSCOPE is 1.8 m, which can be extended to 3.8 m.



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MULTIFUNCTIONAL: TP5008

The TP5008 is an interface card that provides an analogue output in addition to two input channels. This output in combination with the two inputs may be used for the setting up of a complete control loop. The output may also be used as a function generator.
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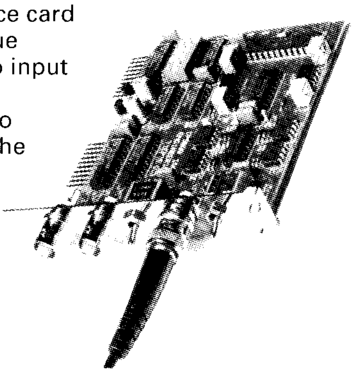

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VERY HIGH SPEED: TP208

The TP208 is an interface card with a measuring speed of 2×20 Megasamples/sec (8 bits). Phenomena shorter than one millionth of a second can still be measured well.
The completely digitized triggering ensures very stable triggering with many trigger possibilities.
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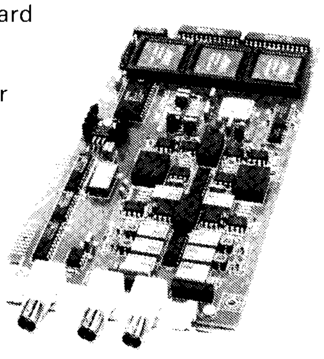

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A LOWER FREQUENCY RECEIVING SYSTEM

The lower frequency regions of the radio spectrum are probably the most unknown, and neglected by the more recent generations of radio listening enthusiasts. Yet, signals, often mysterious, abound, provided one has a good receiver and antenna system. Such a system is described in this article.

By Richard Q. Marris G2BZQ

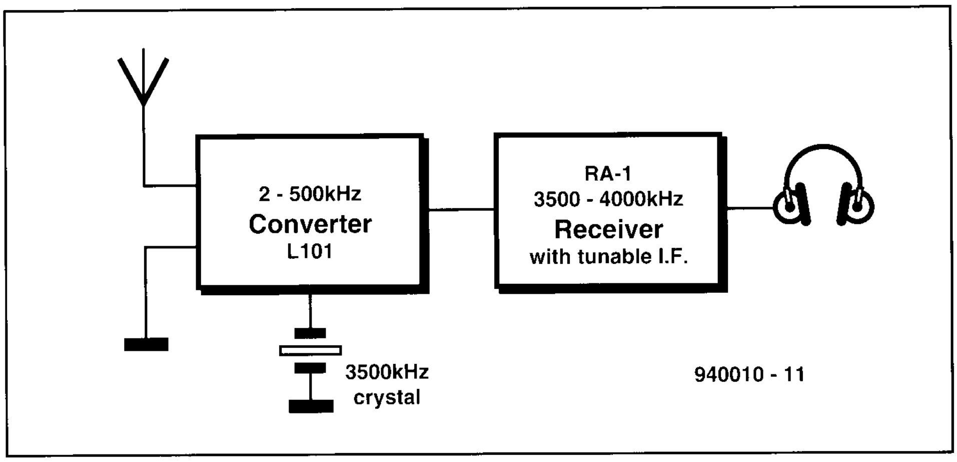

Fig. 1. Block diagram of the VLF receiving system.

FOR convenience, the lower frequency spectrum has been lumped together to include the VLF (very low frequency) bands (2 kHz to 30 kHz, or 150,000 m to 10,000 m), plus part of the MF (medium frequency) band (300 to 500 kHz, or 1,000 m to 600 m). This range does, of course, encompass the European long-wave broadcast band, which is a comparatively small part of the spectrum under consideration.

Those who use the HF bands tend to use the half-wave dipole antenna as a reference. Well, a half-wave dipole at, say, 100 kHz (3,000 m) would be just under 1,500 m (approx. 3,000 ft) long! This gives some idea of the antenna problems at LF.

A suitable receiver must cover the range 2 kHz to 500 kHz (150,000 m to 600 m), and be accurately calibrated at 10 kHz intervals. It must be capable of receiving AM and CW transmissions, and preferably LSB and USB (upper/lower sideband) at the higher frequency end. An AVC (automatic volume control) on/off switch is an advantage, and an adjustable noise limiter is a distinct asset. A tape recorder gives the facility of replaying, and studying, the more mysterious signals; and anyone with RTTY receiving facilities may well be able to use them on occasion.

The receiver

The receiving system used consists of an amateur HF bands communications receiver switched to the 3,500-4,000 kHz band, as a tuneable IF (intermediate frequency) and demodulator, plus a wideband LF converter with a 3,500 kHz crystal oscillator. These units are shown schematically in **Fig. 1**. Any existing amateur band 3,500-4,000 kHz receiver can be used, whether a 'solid state' or older all-tube instrument.

In this particular case, a near perfect 1960's all-tube Heathkit amateur band type RA-1 receiver is used. The LF converter is a tiny circuit board type L-101/80D/PCB purchased from L.F. Engineering Co. Inc. in the USA (Ref. 1). At a price of $39 plus $4 postage, it was just not worth constructing such a unit, as originally intended. The converter is supplied complete with a 3,500 kHz quartz crystal, and came fitted with an on/off switch, a red LED indicator and a battery connector. The circuit uses a PP3 9-V battery, and has a current drain of only 3 mA.

The LF converter uses a high-impedance end-fed antenna input matched to a J-FET mixer type 2N5457, and requires at least a 30-m (100-ft) long end-fed antenna. The result of the arrangement is a wide dynamic range, and higher gain than the more usual low-impedance coaxial feedline input. The output impedance into the main receiver is 50 Ω.

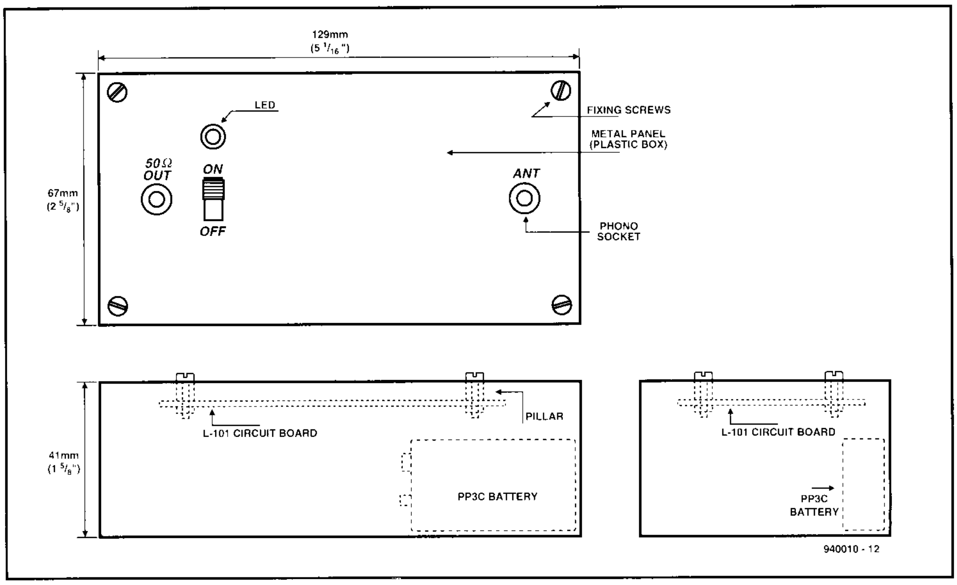

Fig. 2. The VLF converter is built into a small plastic box.

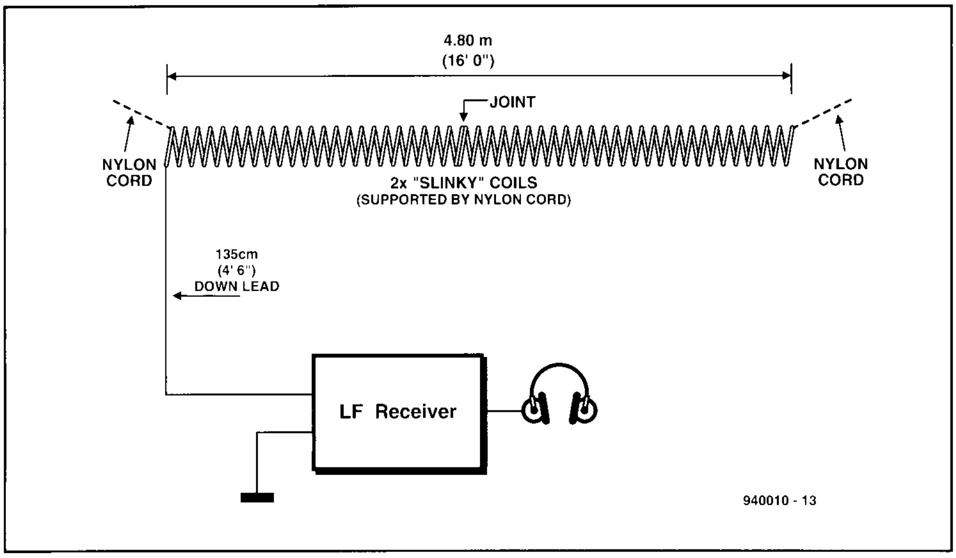

Fig. 3. The 'double-Slinky' end-fed antenna for 2-500 kHz.

The little circuit could be incorporated into the main receiver, or separately boxed. The latter option was adopted, see **Fig. 2**. The converter board is mounted, with battery, in a small plastic box with a metal lid. Throughout the whole system, phono jack sockets and plugs are used for the interconnections.

The LF converter and main receiver are interconnected with RG58 coax cable with a maximum length of about 1.2 m (4 ft). A good ground/earth should be connected to the LF converter.

With a crystal-controlled local oscillator, and crystal calibration in 100-kHz steps on the main receiver used as a variable IF, a high degree of frequency accuracy is achieved. The station frequency is measured by deducting 3,500 kHz from the tuning scale on the main receiver — see **Fig. 6**. Further frequency checks are the various time/frequency standard stations — see later.

Installing a well-elevated 30+ m antenna wire is not achievable by many, especially in built-up areas, where there may be space problems, rules and regulation, and planning permission refusals to contend with.

A number of specialized, compressed, LF antennas have been designed, built and tested. The most suitable are described below.

Antennas for VLF

1. 'Double-Slinky' end-fed antenna (2-500 kHz)

This antenna is shown in **Fig. 3**. It can be mounted indoors or outdoors, taking up an overall physical length of 4.8 m (16 ft) plus a 1.35-m downlead.

The antenna consists of two 'Slinky' coils connected in series. A Slinky coil is a 90-turn 7-cm diameter flexible steel spring, weighing just over 1 kg. Each coil contains 20 m (67 ft) of conductor. When compressed, the Slinky is only about 6 cm long, but can be extended, in a helical configuration, up to about 5 m. Slinky is available from Antenna West in the USA (Ref. 2).

For the double Slinky antenna, two Slinky coils are connected in series, end to end, with a 1.35-m PVC covered flex downlead (which is not a critical length) — see **Fig. 3**. To connect the two coils in series, the end of each coil should have the end turns flow-soldered together.

The 'double Slinky' is supported at either end, on site, by threading white nylon cordage through the coil centre — see **Fig. 3**.

Indoors, the double Slinky may be hung up diagonally across the room, with the downlead dropping down to the LF receiver in the corner of the room. Outdoors the antenna is hung from a window, with the downlead indoors to the receiver, and the whole supported by a nylon cordage to a suitable pole, building or tree.

If used outdoors, it will be necessary to varnish the double Slinky turns to eliminate the possibility of corrosion. The simplest way of varnishing is to suspend the stretched antenna, horizontally, outdoors, at about chest level, and thoroughly spray with varnish. To be absolutely effective, it is recommended to apply three separate coats of varnish.

The double Slinky end-fed antenna is most effective between 2 kHz and 500 kHz, and, in fact, throughout the MW AM broadcast band with other receivers.

2. The end-fed ferrite antenna (95-500 kHz)

This small space-saving antenna consists of a tuned coil wound around a ferrite rod, and end-fed with a 1.2-m lead — see **Fig. 4**. The antenna is very effective, with sharp directional properties, and a sharp 'null'.

The ferrite coil assembly is shown in **Fig. 5**. It consists of a standard 20-cm long × 9.5 mm diameter (8×⅜ in) ferrite rod as used in LW/MW AM broadcast receivers. These rods are available from a number of suppliers, on the surplus market, or can be salvaged from an old broadcast receiver.

The coil winding consists of 12.7 cm (5 in) of close wound turns of 24 SWG (23 AWG) DCC (double cotton covered)

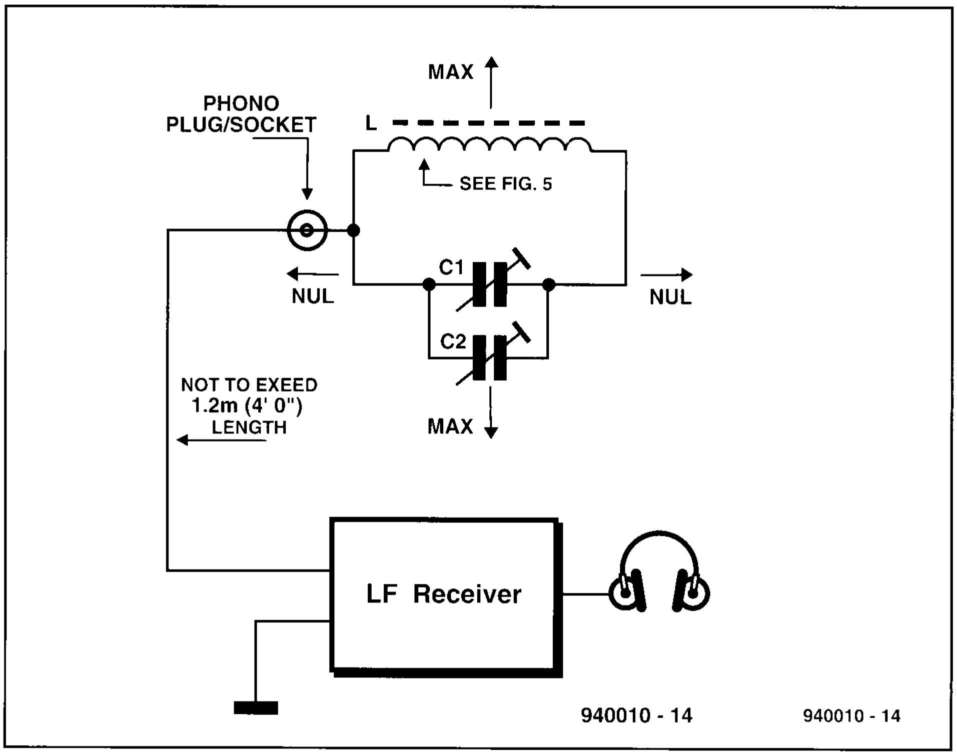

Fig. 4. The end-fed ferrite antenna (95-500 kHz).

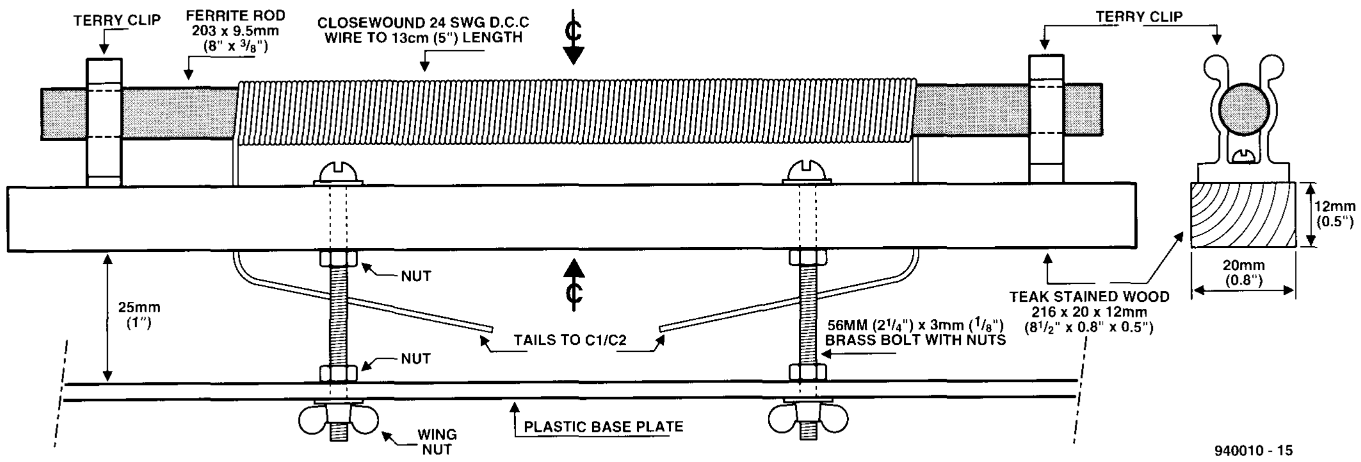
TERRY CLIP
FERRITE ROD 203 x 9.5mm (8" x 3/8")
CLOSEWOUND 24 SWG D.C.C WIRE TO 13cm (5") LENGTH
TERRY CLIP
12mm (0.5")
20mm (0.8")
TEAK STAINED WOOD 216 x 20 x 12mm (8½" x 0.8" x 0.5")
NUT
25mm (1")
TAILS TO C1/C2
56MM (2¼") x 3mm (⅛") BRASS BOLT WITH NUTS
NUT
WING NUT
PLASTIC BASE PLATE
940010 - 15

Fig. 5. Construction of the rod/coil for the end-fed antenna.

copper wire. The winding is centred either side of the middle of the rod. It is much easier to wind a 12.7-cm length than try to count 225 turns of wire. The wire ends are secured with two turns of masking tape, and the whole winding is varnished after initial testing.

The ferrite rod/coil assembly is supported by two plastic coated Terry clips screwed to a strip of teak-stained wood. As shown, the whole assembly is fastened to, and stood-off from, the antenna base plate with two brass bolts. Two nuts and a wingnut are required for each bolt, as shown.

The 1,000-pF variable capacitor (C1+C2) is a standard robust two-gang 500 pF + 500 pF tuning capacitor wired in parallel. Any adjustable trimmers/padders should be removed, and the capacitor should be fitted with an insulated extension spindle.

The simple final antenna assembly is shown in **Fig. 7**. The base plate used was an inverted coloured rigid 22 cm (8.5 in) diameter plastic picnic plate. Alternatively, a plastic or plywood base (22×22 cm), mounted on a 6×6 mm wood framework could be used.

Actual layout positions are not critical, and will depend on the physical size of the two-gang variable capacitor, which is bolted to the base plate as shown in **Fig. 7**.

When in use, the antenna is actually placed on a small turntable to take advantage of its sharp directional effect, which assists in interference elimination.

This end-fed tuned ferrite antenna covers the frequency range from 95 kHz to 500 kHz (3,185 m to 600 m).

Listening around the spectrum

Lower frequencies listening is a completely different ball-game to HF listening. Also, wide differences can be expected between the LF and HF ends of this LF spectrum.

In general, long-distance reception is best during the hours of darkness, especially during the long winter nights. Exceptions do occur. Below about 30 kHz, however, long-distance reception is possible around the clock. Unfortunately, there is not a lot to hear down there. The receiver's CW mode should be used. However, we do have the standard frequency/time signal station GBR (Rugby) at 16 kHz, which has a wavelength of around 19 km — imagine a dipole just under 10 km long! There is also the US Navy submarine communications system which uses frequencies up to about 70 kHz. Very occasionally, high-speed CW stations have been heard, but origins not established. Listening below 30 kHz can be interesting, even if not very enlightening.

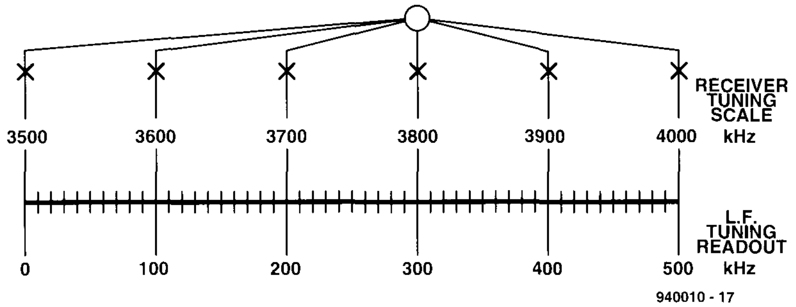

Fig. 6. LF tuning readout.

As we tune upwards in frequency, activity increases from 30 kHz to 500 kHz. Atmospheric static is often a nuisance — it is minimum around noon, and maximum during the hours of darkness. Much of it appears to be directional, and here the end-fed ferrite antenna helps. It has been noticed that as one tunes lower in frequency, from about 500 kHz, the incidence of fading signals appears to decrease.

Probably the most important step for the listener is to establish the location, on the receiver dial, of the various standard frequency and time signal stations that operate around the world. A useful publication is the low-cost *Standard frequency and time signal stations of the world* (Ref. 3), which lists frequencies, callsigns and station locations of 17 such stations between 16 kHz and 500 kHz. It also indicates the various time codes used. A readily available signal is the Loran C navigation aid on 100 kHz, among other navigational systems, to be heard below 150 kHz along with CW signals.

On the average domestic receiver, in Europe, the long-wave AM broadcast band is shown on the dial as from 2,000 m (150 kHz) to 1,100 or 1,000 kHz. It is peculiar to Europe and surrounding countries. Most European countries have an LW broadcasting station, as do several North African countries, such as Algeria and Morocco, and further East, Turkey. LW AM stations also appear to spread through Asiatic Russia.

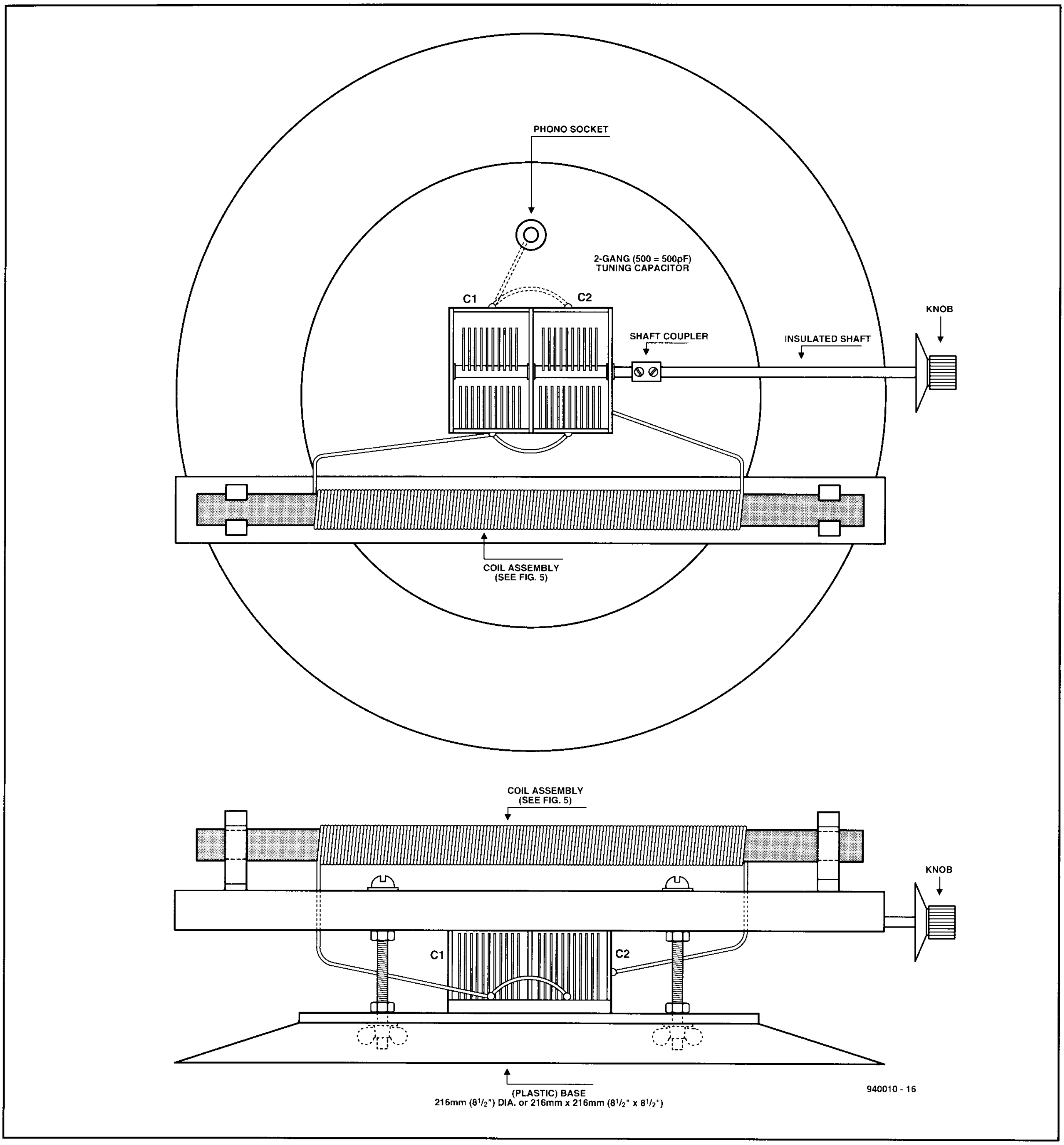
PHONO SOCKET
2-GANG (500 = 500pF) TUNING CAPACITOR
C1
C2
SHAFT COUPLER
INSULATED SHAFT
KNOB
COIL ASSEMBLY (SEE FIG. 5)
COIL ASSEMBLY (SEE FIG. 5)
KNOB
C1
C2
(PLASTIC) BASE
216mm (8½") DIA. or 216mm x 216mm (8½" x 8½")
940010 - 16

Fig. 7. Construction of the end-fed ferrite antenna assembly, which is mounted on a turntable.

Another relatively unknown fact, in Europe, is the existence of the 1,750-m Amateur Experimental Band which is available in the USA, Canada and in some Pacific areas. This band covers the frequency range from 160 kHz to 190 kHz, and there is the Long Wave Club of America (Ref. 4) which publishes a monthly magazine called *Lowdown*. Recently it has been read that Australian (and possibly New Zealand) amateurs are using 196 kHz for transmission and reception. Additionally, there is a multitude of worldwide air/marine navigational beacons, weather and information stations, etc. These can be heard readily throughout the LW band, except in Europe, where they may be blanketed by the LW broadcast stations. Some of them may still be heard, however, between 270 kHz and 500 kHz. Also between 300 kHz and 500 kHz the odd AM and SSB station may be heard, plus CW and occasional RTTY. There is much which is not readily identifiable, and a tape recorder is an asset to study these signals later. ■

References and addresses:

1. L.F. Engineering Co. Inc., 17 Jeffry Road, East Haven CT06513, USA.

2. Antenna West, 1500 North 150 West, Provo UT84604, USA.

3. *Standard frequency and time signal stations in the world*, published by the International Short Wave League, and obtainable from the Hon. Secretary, 10 Clyde Crescent, Wharton, Winsford, Cheshire CW7 3LA, England.

4. The Long Wave Club of America, 45 Wildflower Road, Levittown PA 19057, USA.

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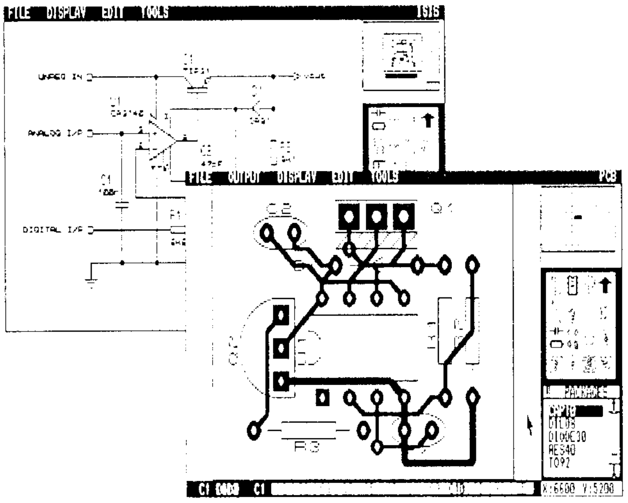

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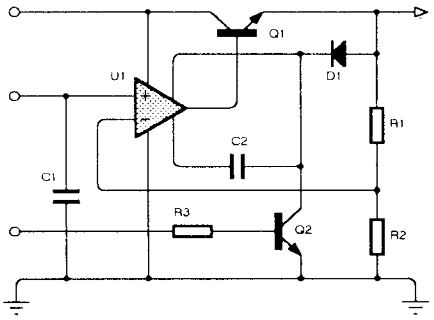

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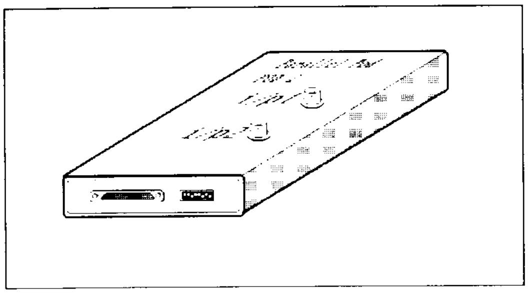

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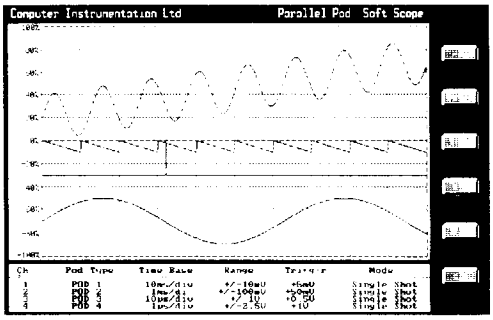

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2	POD 2	1ms/div	+/-100mV	+50mV	Single Shot
3	POD 3	10µs/div	+/-1V	+0.5V	Single Shot
4	POD 4	1µs/div	+/-2.5V	+1V	Single Shot

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HEADPHONE AMPLIFIER

Design by T. Giesberts

Music should be heard and enjoyed as if the orchestra were right in front of you. Unfortunately, neighbours, children and other members of the family may not be as keen as you on the particular piece of music you are enjoying. The answer to this is, of course, the use of headphones. These also have the advantage of offering a quality of reproduction that only loudspeakers costing at least ten, and probably twenty, times as much as the headphones would be able to equal.

A first-class electroacoustic transducer, whether this is a headset or a loudspeaker, can only perform to its true specification if the amplifier driving it is also first class. It is, of course, not necessary to connect a headset to a power amplifier; after all, it needs only little energy. Yet, in practice, the headphone output is often taken from the power amplifier output via a potential divider. It is, however, far better to connect it to the output of the preamplifier via a dedicated headphone amplifier as described in this article.

A headphone amplifier is, strictly speaking, a sort of line amplifier with a power output. Its amplification need not be high, since the sensitivity of most headsets is usually fairly good. If we assume that the output of the preamplifier is 1 V r.m.s., an amplification of a few times is quite sufficient: some tens of milliwats is fine.

Average good-quality headphones provide a sound pressure of 90–100 dB for an input of about 1 mW. It should be borne in mind that modern headphones have a fairly high impedance. Until not so long ago, this impedance was 8 Ω or so, but nowadays good-quality headphones have an impedance of hundreds of ohms (typically 600 Ω). The present amplifier can deliver up to 40 mW into 600 Ω. Never use this full power for listening long: it may permanently and irreversibly damage your hearing. **Too many young people are going deaf prematurely because they listen to headphones at too high a volume!**

Note that the amplifier is not suitable for use with electrostatic headphones. These need far more energy and are, therefore, normally driven straight from the power output amplifier.

The circuit

The design—see **Fig. 2**— is a pure symmetric one which can be split into an amplifier that works from a positive supply and one that operates with a negative supply. This design, used in the past in preamplifiers for moving-coil pick-ups, is known for its excellent performance at low drive levels. However, it appears to do well also at higher signal levels. Its only drawback is the requirement for two input capacitors: one for the n-p-n stage and one for ther p-n-p stage. But, since in a headphone amplifier the input impedance may be fairly high (here about 20 kΩ), these 2.2 µF capacitors can be kept fairly small so that good-quality ones (polyethene or polypro-pylene) can be used.

The signal from the preamplifier is applied to R_1. This resistor and C_1 form a low-pass filter that limits the bandwidth of the incoming signal to about 400 kHz for a preamplifier output impedance of 600 Ω. The signal is then applied to amplifiers T_1 and T_2 via capacitors C_2 and

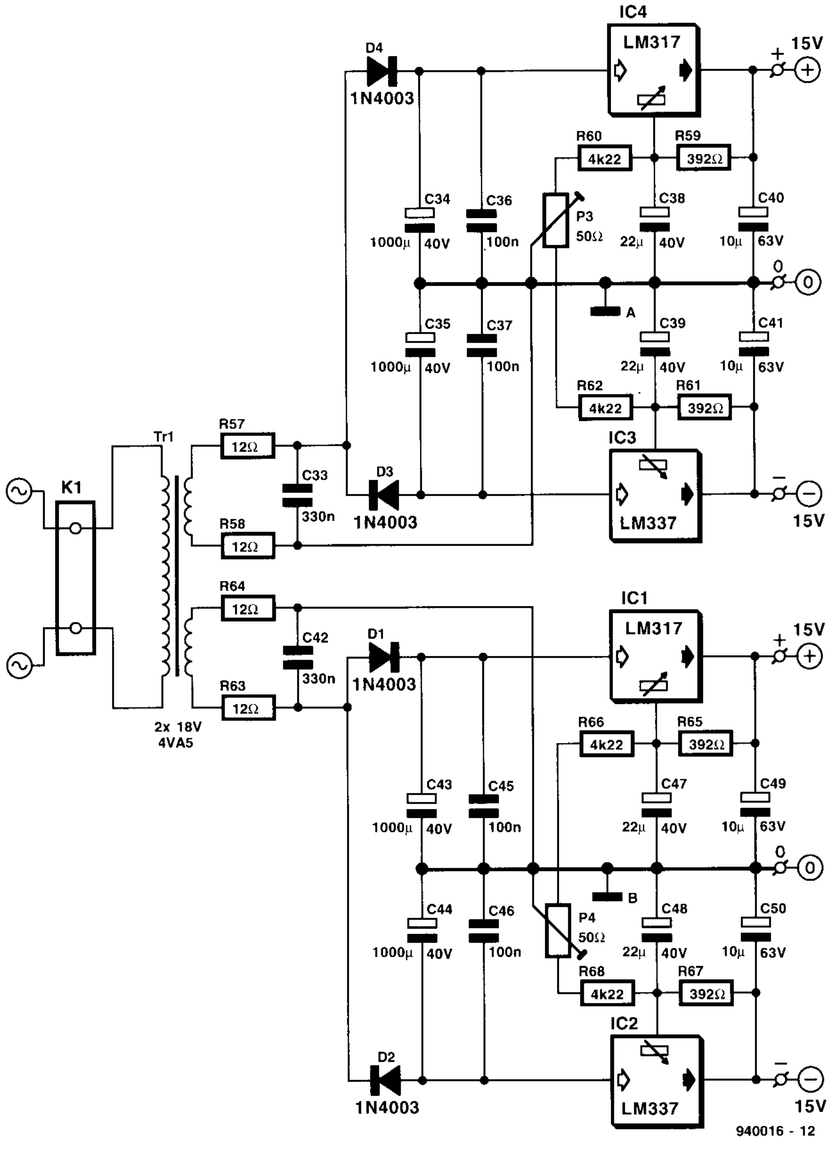


Fig. 1. Circuit diagram of the double power supply for the headphone amplifier.

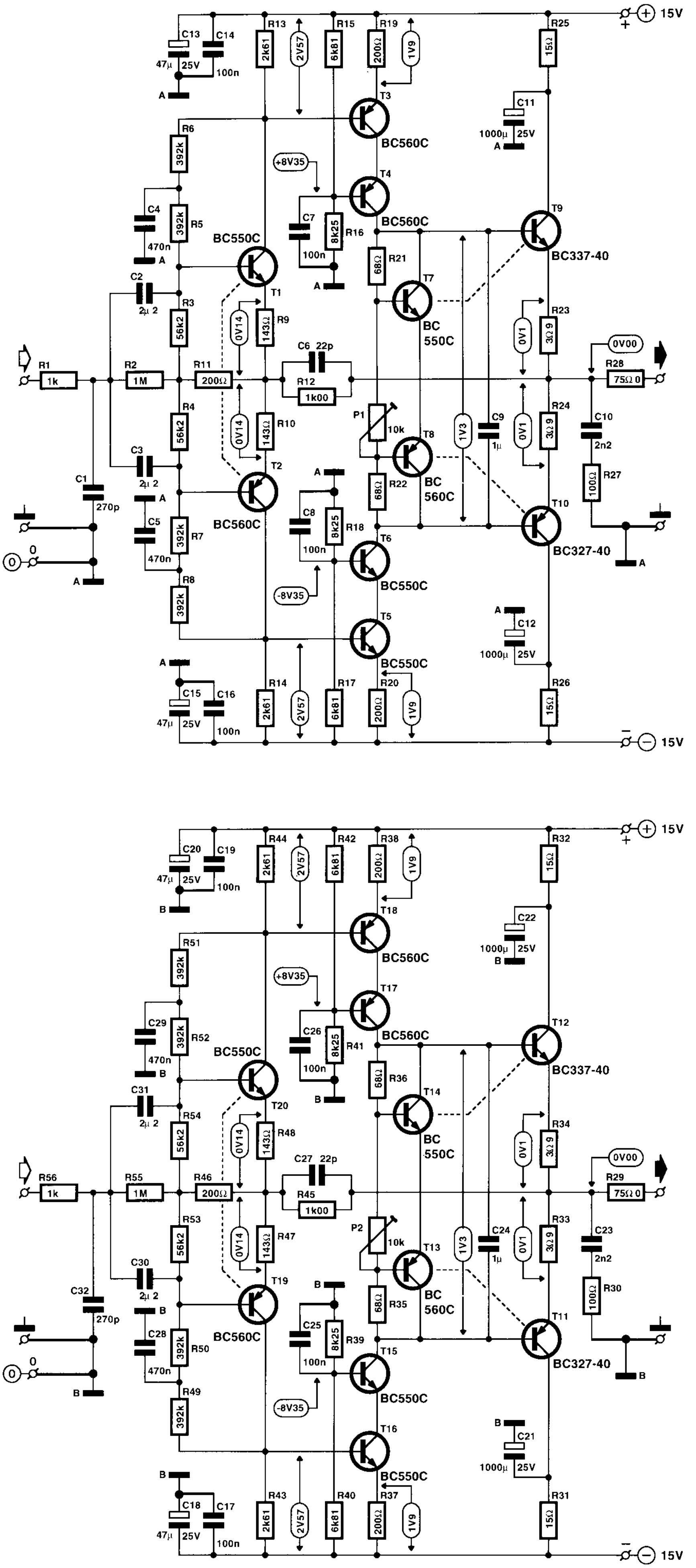


Fig. 2. Circuit diagram of the stereo headphone amplifier.

C_3. The amplification of these stages depends on the values of R_9, R_{11}, R_{13} (in the case of T_1) andR_{10}, R_{11}, R_{14} (in the case ofT_2). Resistor R_{11} is also part of the feedback loop of both transistors. The d.c. operating point is set by R_3-R_5-R_6 (T_1) and R_4-R_7-R_8 (T_2). These resistors alsop provide some local feedback.

The signals at the collector of T_1 and T_2 are fed to two cascode stages, T_3-T_4 and T_5-T_6 respectively. These stages provide wide-band amplification and impedance matching between the input transistors and the 'output' stage. A drawback of this arrangement is that output transistors can not be driven up to the supply voltage level, but that is not so important in the case of a headphone amplifier. The output transistors are driven by the collector signals of T_4 and T_6.

Transistors T_7 and T_8 form an adjustable 'zener' stage that sets the quiescent current. They are thermally coupled with T_9 and T_{10} to ensure that the quiescent current remains reasonably stable during temperature variations in the output transistors.

The current through T_9 and T_{10} is relatively high (25 mA), which is typical of Class A operation. The transistors are connected to the power supply via 15 Ω resistors, buffered by electrolytic capacitors C_{11} and C_{12}.

Overall feedback is provided by R_{12}. Together with R_{11}, this resistor determines the amplification of the complete amplifier.

Network R_{27}-C_{10} ensures a constant load at high frequencies.

The output impedance is 75 Ω (R_{28}). Power amplifiers normally have a low output impedance, but headphone amplifiers need a higher one. On the one hand, a low impedance ensures that the varying impedance of the headphones does not influence the output characteristic, and on the other hand, a resistor is necessary to protect the output stage against short circuits that occur every time the jack plug of the headphones is inserted into the socket. The specified value of R_{28} was found to be a good compromise.

Since a stereo amplifier draws a fairly high current, the amplifier is given a dedicated power supply—see **Fig. 1**. To ensure strict separation of the channels, the mains transformer uses two secondary windings, each of which provides a symmetrical voltage of ±15 V. In this way, only two windings are needed for two isolated symmetrical voltages. Deriving symmetrical voltages from a single winding is possible with half-wave rectification: one diode uses the positive half-periods to charge an electrolytic capacitor, and another diode rectifies the negative half-periods. The use of relatively large electrolytic smoothing capacitors ensures that the ripple is kept small in spite of the half-wave rectification. Resistors R_{57}, R_{58}, R_{63} and R_{64} limit peak currents.

Integrated circuits IC_1–IC_4 regulate the output voltages, which are held at ±15 V with the aid of resistance networks. Presets P_3 and P_4 enable setting exactly symmetrical voltages and setting the output of each output stage to exactly zero.

Construction

The complete amplifier is best built on the printed-circuit board in **Fig. 4**. This board consists of three parts: left-hand channel amplifier, right-hand channel amplifier and power supply. It is advisable to cut the board into three parts, so that the power supply can be fitted some distance from the amplifiers.

Population of the boards is straightforward, but make sure that the flat sides of transistor pairs T_1-T_2, T_7-T_9, T_8-T_{10}, T_{19}-T_{20}, T_{12}-T_{14} and T_{11}-T_{13} fit snugly together. Make two small rings of copper or aluminium and use these to clamp T_1 and T_2, and T_{19} and T_{29}, securely together for good thermal contact. Fit lobe-finned heatsinks as used for TO-39 transistors around the other four pairs. These heatsinks should be slightly flattened before fitting them—see **Fig. 3**.

Interwiring is minimal: six wires for the supply voltages.

It is advisable to build the amplifier in a dedicated case, since most preamplifier will not have the space to house it. Fit the mains entry at the back of the case and the audio input sockets and the (6.3 mm) jack socket at the front. **Figure 5** shows how this must be wired.

When the construction is completed, set P_3 and P_4 to the centre of their travel. Connect a multimeter (200 mV direct voltage range) across R_{23}. Adjust P_1 until the voltage across R_{23} is 100 mV. Do the same in the other channel with P_2 and R_{34}.

Connect the multimeter to the output of each amplifier in turn and adjust P_3 and P_4 respectively for zero reading of the meter (50 mV range).

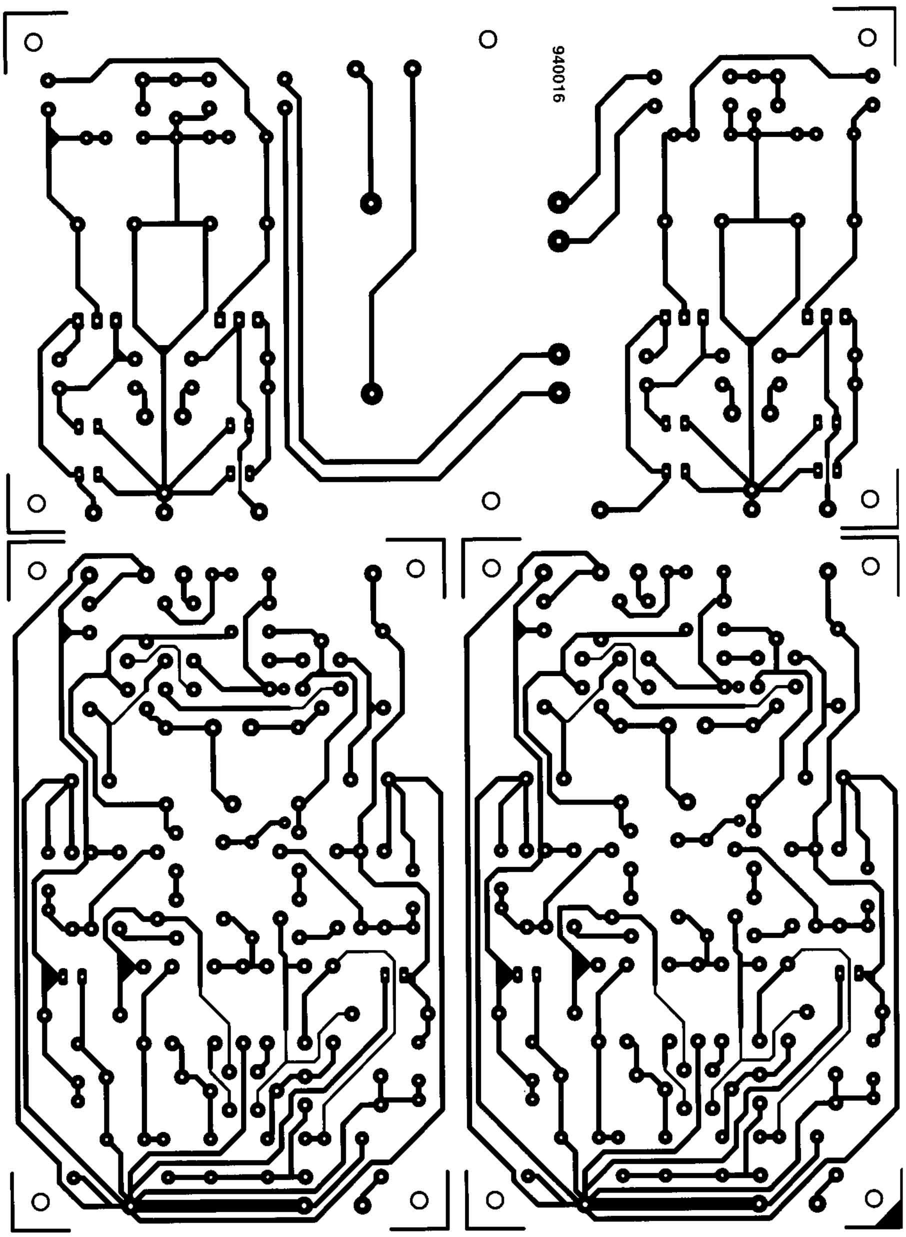


Fig. 4. The printed circuit board for the headphone

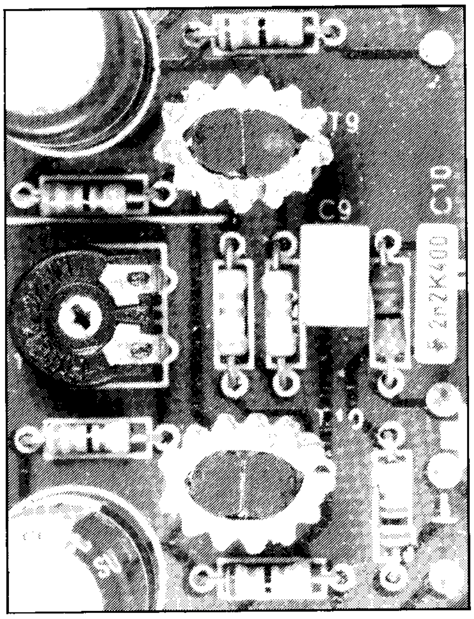


Fig. 3. This photograph shows how the pairs of transistors should be thermally coupled with the aid of a slightly flattened lobe-finned heatsink (TO39 size).

Parts list

Resistors:

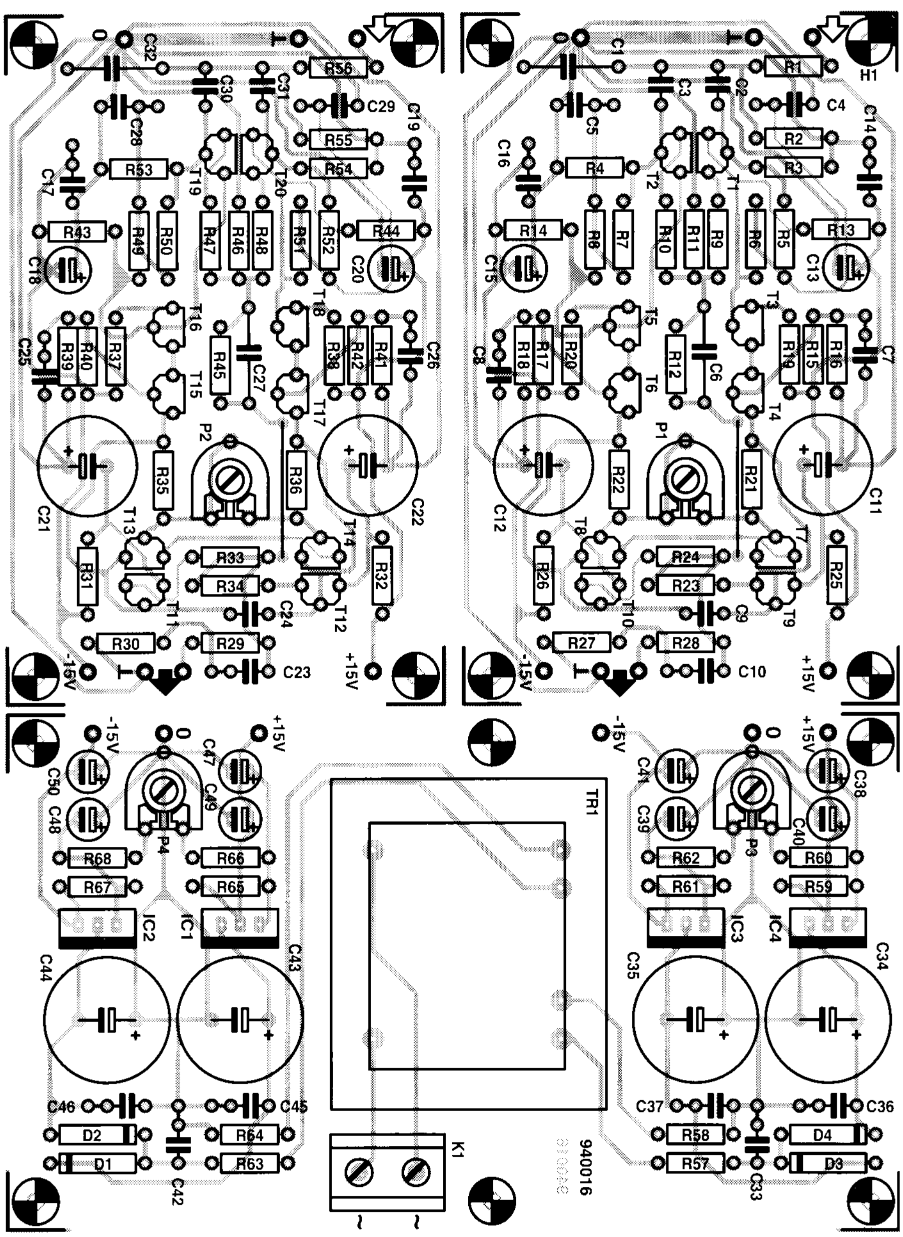
R_1, R_{56} = 1 kΩ

R_2, R_{55} = 1 MΩ

R_3, R_4, R_{53}, R_{54} = 56.2 kΩ, 1%

Main parameters

Supply voltage	±15 V
Current drain (each output stage)	about 30 mA
Quiescent current (each output stage)	25 mA
Output power	40 mW into 600 Ω
THD + noise (at 1 mW into 600 Ω)	<0.0015% (20 Hz–20 kHz)
THD at 1 kHz/1 mW	<0.0005%
Signal-to-noise ratio	>112 dB (A-weighted)
Input impedance	about 20 kΩ
Output impedance	75 Ω
Bandwidth	400 kHz
Slew rate (without R_1-C_1)	350 V µs^{-1}
Allowable loads	33–600 Ω



amplifier should preferably be cut into three.

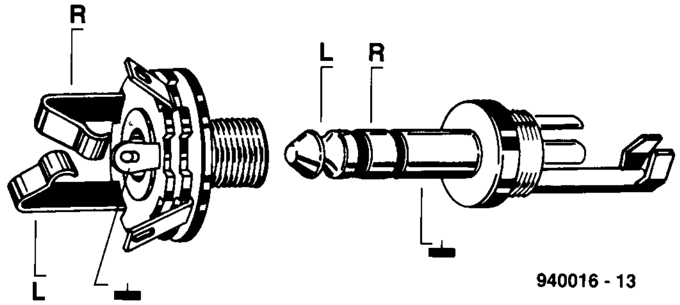


Fig. 5. Wiring details of a 6.3 mm jack plug and socket.

R_5–R_8, R_{49}–R_{52} = 392 kΩ, 1%
R_9, R_{10}, R_{47}, R_{48} = 143 Ω, 1%
R_{11}, R_{19}, R_{20}, R_{37}, R_{38}, R_{46} = 200 Ω, 1%
R_{12}, R_{45} = 1.00 kΩ, 1%
R_{13}, R_{14}, R_{43}, R_{44} = 2.61 kΩ, 1%
R_{15}, R_{17}, R_{40}, R_{42} = 6.81 kΩ, 1%
R_{16}, R_{18}, R_{39}, R_{41} = 8.25 kΩ, 1%
R_{21}, R_{22}, R_{35}, R_{36} = 68 Ω
R_{23}, R_{24}, R_{33}, R_{34} = 3.9 Ω
R_{25}, R_{26}, R_{31}, R_{32} = 15 Ω
R_{27}, R_{30} = 100 Ω
R_{28}, R_{29} = 75.0 Ω, 1%
R_{57}, R_{58}, R_{63}, R_{64} = 12 Ω
R_{59}, R_{61}, R_{65}, R_{67} = 392 Ω, 1%
R_{60}, R_{62}, R_{66}, R_{68} = 4.22 kΩ, 1%
P_1, P_2 = 10 kΩ preset
P_3, P_4 = 50 Ω preset

Capacitors:
C_1, C_{32} = 270 pF, polystyrene
C_2, C_3, C_{30}, C_{31} = 2.2 µF, 50 V, polythene or polypropylene, pitch 5 mm
C_4, C_5, CC_{28}, C_{29} = 470 nF
C_6, C_{27} = 22 pF, polystyrene
C_7, C_8, C_{14}, C_{16}, C_{17}, C_{19}, C_{25}, C_{26}, C_{36}, C_{37}, C_{45}, C_{46} = 100 nF
C_9, C_{24} = 1 µF, pitch 5 mm
C_{10}, C_{23} = 2.2 nF
C_{11}, C_{12}, C_{21}, C_{22} = 1000 µV, 25 V, radial
C_{13}, C_{15}, C_{18}, C_{20} = 47 µF, 25 V, radial
C_{33}, C_{42} = 330 nF
C_{34}, C_{35}, C_{43}, C_{44} = 1000 µF, 40 V, radial
C_{38}, C_{39}, C_{47}, C_{48} = 22 µF, 40 V, radial
C_{40}, C_{41}, C_{49}, C_{50} = 10 µF, 63 V, radial

Semiconductors:
D_1–D_4 = 1N4003
T_1, T_5–T_7, T_{14}–T_{16}, T_{20} = BC550C
T_2–T_4, T_8, T_{13}, T_{17}–T_{19} = BC560C
T_9, T_{12} = BC337-40
T_{10}, T_{11}, = BC327-40

Integrated circuits:
IC_1, IC_4 = LM317
IC_2, IC_3 = LM337

Miscellaneous:
K_1 = 3-way terminal block, pitch 7.5 mm
Tr_1 = mains transformer, secondary 2×18 V, 4.5 VA
PCB Ref. 940016 (see page 70)

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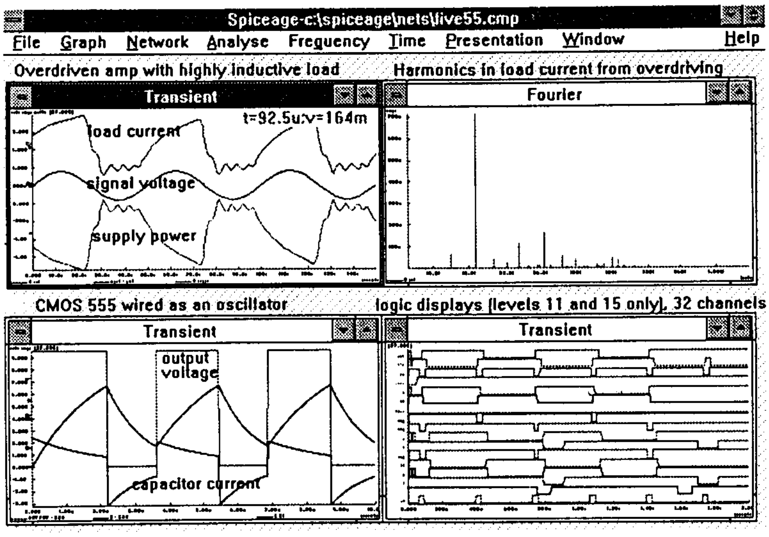
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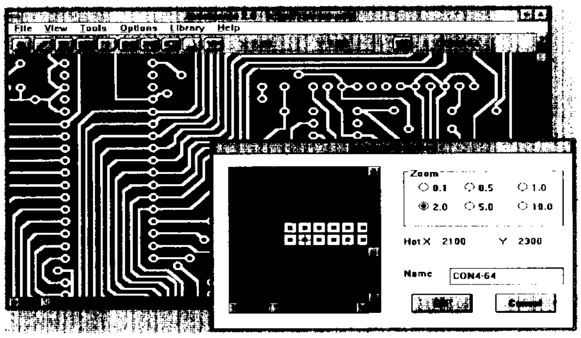

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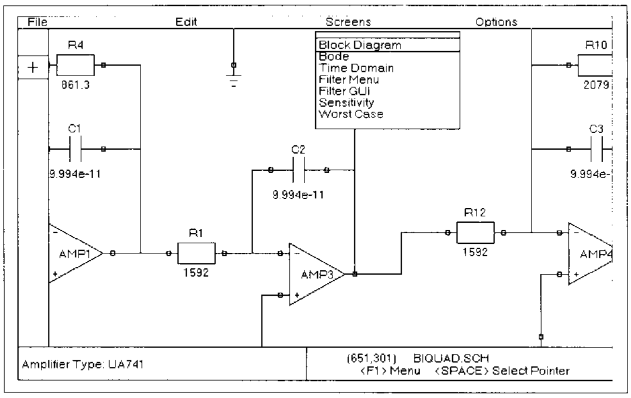

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Handshake	None, RTS/CTS, XON/XOFF	None, RTS/CTS, XON/XOFF
Data format	Motorola s1f, s2f and s3f	Motorola s1f, s2f and s3f
Socket	ZIF-28	ZIF-32
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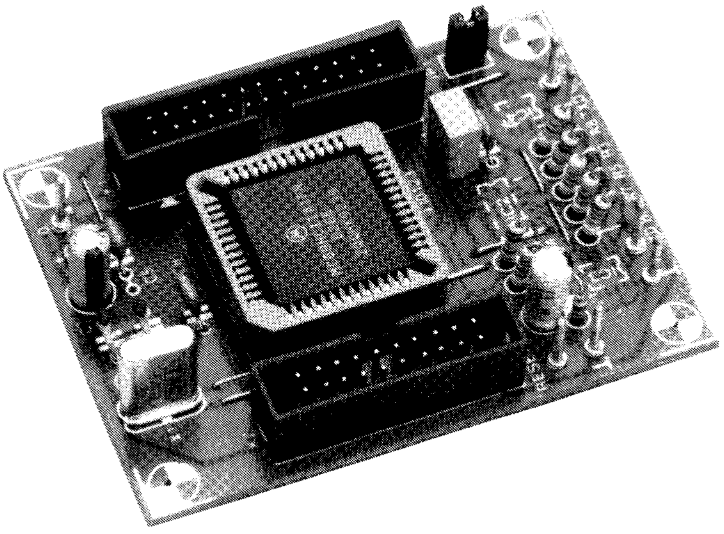
68HC11 PROCESSOR BOARD

The processor board discussed in this article is remarkably easy to program thanks to an EEPROM contained in the 68HC11 microcontroller. Expensive programmers or complex protocols are not required — all you need is a serial link with a PC. What's more, development software is available free of charge on two Motorola bulletin boards.

MAIN SPECIFICATIONS

Processor:	68HC11A1T
RAM:	256 bytes
EEPROM:	512 bytes
Clock frequency:	8 MHz
Software:	freeware on bulletin board
Communication;	via RS232 port
PCB:	single-sided
I/O:	22 lines available



(actual size)

Design by J. Scherer and A. Hermann

MOTOROLA'S microcontroller product range is very extensive, offering processors which contain ROM, EPROM, or EEPROM as a standard feature. Also available on these ICs is a host of I/O ports. For the present project, the 68HC11 was chosen. The block diagram of this processor is given in **Fig. 1**. The CPU operates at a nominal bus frequency of 2 MHz, which equals the oscillator frequency divided by four. The processor is a 'fully static' type, which means that it can work at very low clock frequencies, even lower than 1 Hz.

The main sub-circuits of the controller are: a powerful 16-bit timer with internal prescaler; energy-saving halt and wait modes; a serial interface geared to driving I/O components; a serial communication bus; an 8-bit counter and a real-time interrupt circuit. Additionally, the 68HC11 used for the present project has an EEPROM memory of 256 bytes, and an 8-channel, 8-bit A-D (analogue-to-digital) converter. The structure of the processor will be reverted to in greater detail below.

The circuit

The power of the concept is immediately apparent from the sheer simplicity of the circuit diagram shown in **Fig. 2**. Apart from a clock oscillator based around an 8-MHz quartz crystal (R_1, C_1, C_2 and X_1), a reset circuit (R_2, C_3) and two opto-isolators (IC_3 and IC_4), there is only a handful of other components which couple the subcircuits. Since only internal program memory is used, most of the 52 pins of the processor are available for control applications. This also brings out the main disadvantage of the concept: your program may not be larger than 512 bytes!

The processor's serial interface arranges the communication between the development system and the control computer. Via this interface, software is exchanged between the control computer and the controller board. If jumper JP_1 is not fitted, the processor automatically starts a small internal program after a reset. This routine waits for information to appear on the serial channel. Depending on the first byte transmitted on this channel (the byte must be FF_H in this application), the serial port is initialized at 1200 baud. The next 256 bytes transmitted are stored in the controller's RAM (random access memory). At the same time, they are returned to the computer via the TxD (transmit data) link. As soon as the 256th byte is received (i.e., the 257th including the FF_H header byte), the serial routine is automatically interrupted, and the processor starts to execute the program it has just finished storing in RAM. This 'bootstrap' method is very useful for testing small programs. There is, however, another application for this very special feature of the 68HC11. If the RAM is loaded with a program which arranges for received data to be stored into the 512-byte EEPROM, the controller can be programmed automatically. The program copied into the EEPROM in this way remains intact until it is overwritten by a new program.

After using the downloader to copy a user program into EEPROM, you obviously must be able to start this program. The following option has been provided by Motorola to achieve this: when the first byte which appears at the serial input is 00_H, the CPU starts to execute the program contained in EEPROM. This requires fitting jumper JP_1. After a power-up reset, a positive going pulse transition appears automatically at the TxD output. This pulse is fed to the RxD input via electronic switches IC_{2a} and IC_{2b} (4066), and the closed jumper. Since electronic switch IC_{2b} blocks the serial connection if it is closed (RxD and TxD are then interconnected), the reset circuit breaks this connection after 15 ms, whereupon the serial interface is available again for 'normal' work.

Building the processor board

As shown in **Fig. 3**, the printed circuit board designed for the 68HC11 processor board is compact and single-sided. The component mounting plan indicates that components are fitted at both sides of the board. Integrated circuits IC_2, IC_3 and IC_4 are surface-mount devices (SMDs), which are fitted at the track (copper) side of the board. Use thin solder wire, and a low-power (8 W) solder iron with a fine tip to mount these SMDs. Great care and precision should be exercised when fitting the 52-pin socket for the controller. Remember, a short-circuit is easily made, but difficult to trace later. After fitting the nine wire links, six solder pins, the jumper socket and connectors K_1 and K_2, the remaining components may be fitted on to the board. Keep an eye on the polarity of the electrolytic capacitors.

If difficult to obtain, the SMD versions of the opto-isolators may be replaced by normal size equivalents like the IL201, IL202 or the TIL111. A few short wires may be used to connect these parts to the respective solder spots originally provided for the SMD parts.

Software, the key to success

A vast collection of programs written for the 68HC11 is available free of charge from Motorola's bulletin boards in München, Germany, telephone (+49) 8992 103111, and in Austin, Texas, in the U.S.A., telephone (+1) 512 8913733. Fortunately for readers in the UK, the German bulletin board communicates in English. The following programs are needed for the present board:

for the downloader:
EEPROGIX.ASC
EEPROGIX.BOO
EEPROGIX.REC
E9CONFIG.BAS

for the assembler:
ASMHC11.COM
ASMHC11.HLP
CODES.ASC
OFFSET.ASC
RECBIN.COM
RECBOOT.COM
REG HC11.ASC

for the mini-debugger:
CONFIG.ASC
CONFIG.BAT
CONFIG.BOO
MINIBUG.ASC
MINIBUG.BOO
MINIBUG1.BAT
MINIBUG2.BAT

Downloading these programs from the bulletin boards is fairly easy. Dial up using a PC, a modem and a communications program, for instance, Procomm. Use the following lime settings: 2400 baud, no parity, 8 databits, 1 stop bit. As soon as you are connected, press the ENTER key, where-

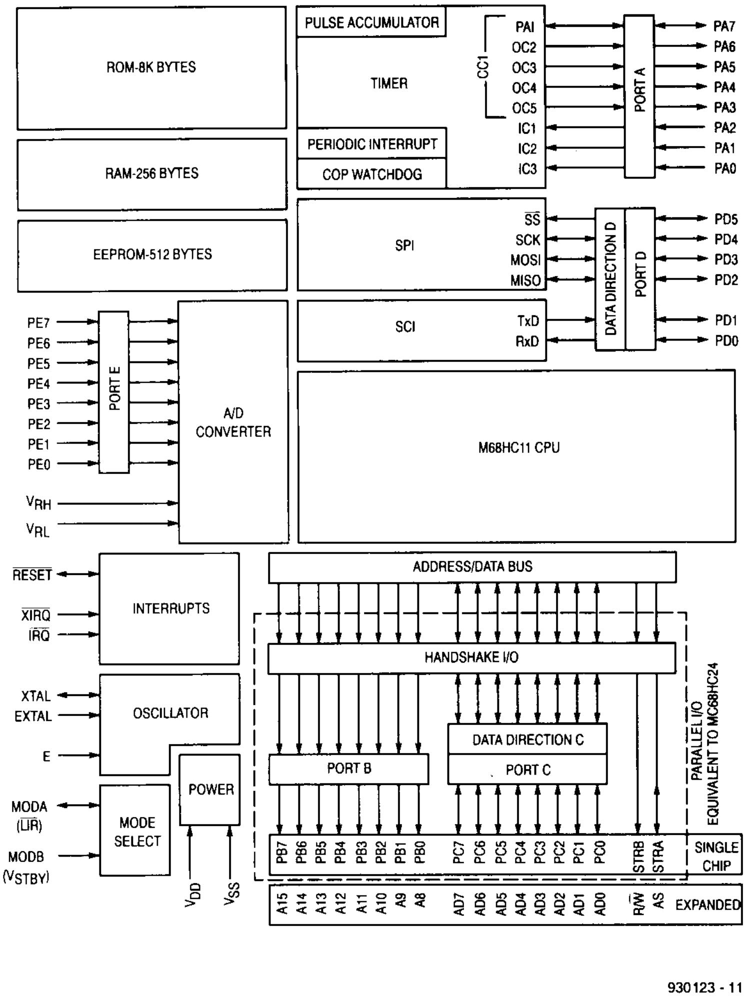


Fig. 1. Block diagram of the 68HC11A8 processor. This IC is the 'generic' HC11 processor, from which the A1version (used in the present project) is a smaller derivate.

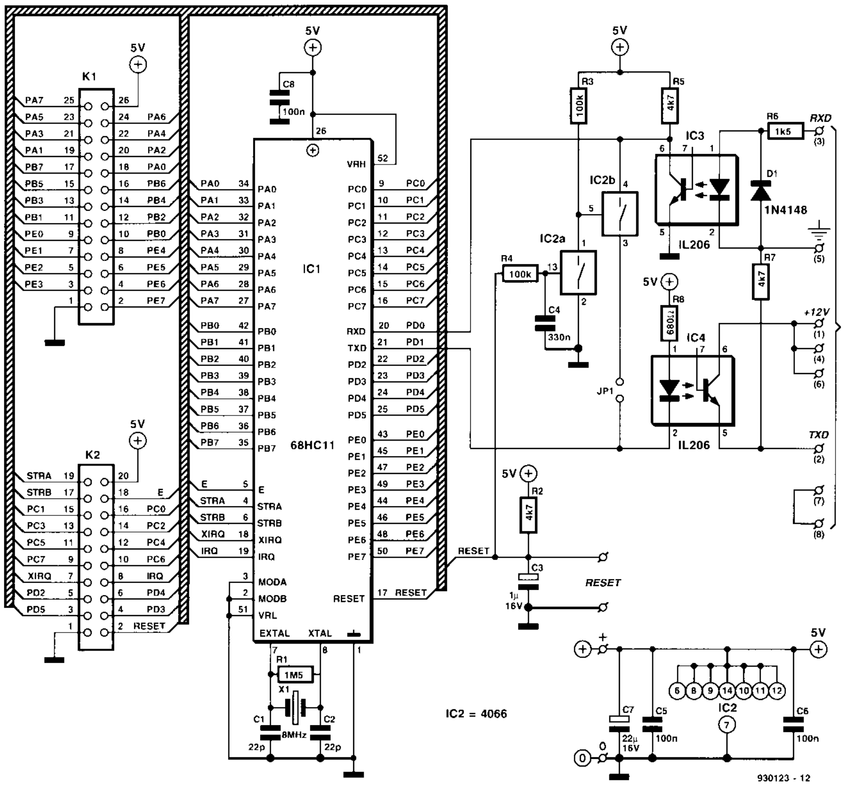


Fig. 2. Circuit diagram of the 68HC11 processor board.

INTRODUCING THE 68HC11 FAMILY

Motorola's 68HC11 family of microcontrollers consists of a range of 8-bit processors marked by a number of powerful I/O functions. The family essentially consists of four members: 68HC11A0, 68HC11A1, 68HC11A7 and 68HC11A8. These processors are manufactured in high-speed CMOS technology, which guarantees fast operation in combination with low power. Depending on the exact IC type, the on-chip memory is an 8-kByte ROM, a 512-byte EEPROM, a 256-byte static RAM, or a combination of these.

The instruction set used to program these processors is an extended version of the one known for the 'older' 6800 or 6801. This enables software written for the 6800, 6801 or 6805 to be run on the 68HC11 without problems.

The family is 'built' around the 68HC11A8, a processor with an on-chip 512-byte EEPROM, and a 256-byte RAM. A number of other ICs were developed on this basis, as shown by the following table.

Type	**EPROM**	**RAM (bytes)**	**EEPROM (bytes)**	**I/O lines**	**A-D channels**
68HC11A0	-	256	-	22	8
68HC11A1	-	256	512	22	8
68HC11A7	8K	256	-	38	8
68HC11A8	8K	256	512	38	8

Depending on the programmer's selection, the CPU has either two 8-bit wide accumulators, or a single 16-bit accumulator. Furthermore, there are two 16-bit wide index registers. Up to six addressing methods are available, including direct, indirect and immediate. STOP and WAIT modes are available to reduce the power consumption of the processor when it is not active.

The chip also contains a 16-bit timer, which is fed by a software controlled prescaler. The addressing range of the external address bus is 64 KByte.

Memory

The largest option comprises the use of memory. The processor is capable of working with RAM, ROM, EPROM or EEPROM memory. The size of the ROM memory varies between 0 K and 32 KByte. The ROMs are mask-programmed with the application program during the production process. This is done by Motorola.

Another important memory area is the RAM, whose size varies between 192 bytes and 1.25 Kbyte. The processor's RAM is static, and may be made non-volatile by backing up the supply voltage with the aid of a battery.

The size of the EPROM area varies between 4 and 32 KByte. This section of the memory is particularly valuable when developing prototypes, or producing low-volume series. For this purpose, Motorola also supplies an OTP (one-time programmable) version of the processor.

The last memory option is the EEPROM, whose size can vary between 0 and 2 KByte. The EEPROM memory area may be used to store calibration information, data logging data, security codes, etc. This makes the EEPROM eminently suitable for quasi-permanent storage of important data. Each 68HC11 with an on-board EEPROM also contains the hardware necessary to program this memory. External hardware is not required!

I/O options

The processor contains an 8-channel A-D converter. All processors feature a Serial Peripheral Interface (SPI), which allows special I/O components having the same interface to be connected in a simple manner. Furthermore, there is a Serial Communications Interface (SCI). The operation and layout of these interfaces is so 'clever' that they hardly load the CPU.

The SCI is a full-duplex UART (universal asynchronous receiver/transmitter) suitable for asynchronous communication. An internal baudrate generator supplies the UART clock frequency, which is derived from the microcontroller's clock signal. Both the transmitter and the receiver feature double buffering.

The SPI is a four-wire synchronous interface designed to enable high-speed communication between the processor and I/O components, or for inter-processor traffic. Only components having an SPI interface may be connected to this bus. Data may be transmitted and received simultaneously. The baudrate on the SPI is programmable.

The processors have a wide variety of I/O lines available for different control functions. These lines may be set up as inputs or outputs by programming the Data Direction Register contained in the processor. Most I/O ports have a buffer.

A built-in watchdog timer alerts the processor if something goes wrong during the execution of a program. All processors may be used at a supply voltage of 3 V.

upon the Motorola bulletin board menu appears. Every screen tells you which key you should press to be able to continue. First, you are prompted to enter your name, personal password, and the transmission protocol used. After a few entries (which include questions regarding the bulletin boards you wish to see — answer 'N' most of the time), the welcome menu appears, followed by the main menu. Type 'D' to select downloading. The program will ask you for a file name, and then tells you whether or not that file is available on the system. Use a protected protocol such as XMODEM or YMODEM to do the actual downloading. This is necessary to make sure that transmission errors are detected and corrected.

Procomm starts downloading using the XMODEM protocol after pressing the 'page-down' key, and entering the name of the file you wish to receive. Files can be downloaded one after another. By contrast, in YMODEM mode, you make a list of all files you wish to download. If you are a frequent bulletin board user, will have no problems in getting what you want from the Motorola databanks. None the less, a few alternative possibilities: in the main menu, you may change the download protocol (if necessary) by pressing 'Y'. In the file menu, pressing 'L' allows you to call up the names of the available files. Next, you can select an 'area' by pressing '?', in this case, 'B' for HC11 freeware. The latter option is certainly worth trying, because a lot of interesting files are available.

Assuming that you have successfully downloaded the above programs, a couple of small modifications have to be made in E9CONFIG.BAS. Line 170 of this program contains a reference to EEPROGE9.BOO. This must be changed to read EEPROGIX.BOO. This program is the first to be copied into the RAM memory of the 68HC11 by the BASIC routine. Once started, EEPROGIX.BOO ensures that data which reaches the processor via the serial interface is stored into EEPROM. In this way, the processor is programmed with the application program.

Line 180 should contain a '1' or a '2' to point to the respective serial port on the PC, COM1: or COM2:. Line 200 enables the user to select between internal or external programming. The available options are 'I' for internal, 'X' for external, and 'V' for verify.

Line 210 should contain the name of the program to be sent to the controller. The extension for the program file name must be .REC, and the file should have the Motorola S19 format. The assembler which forms part of this development environment turns a source (.ASC) text file into S19 format (.REC).

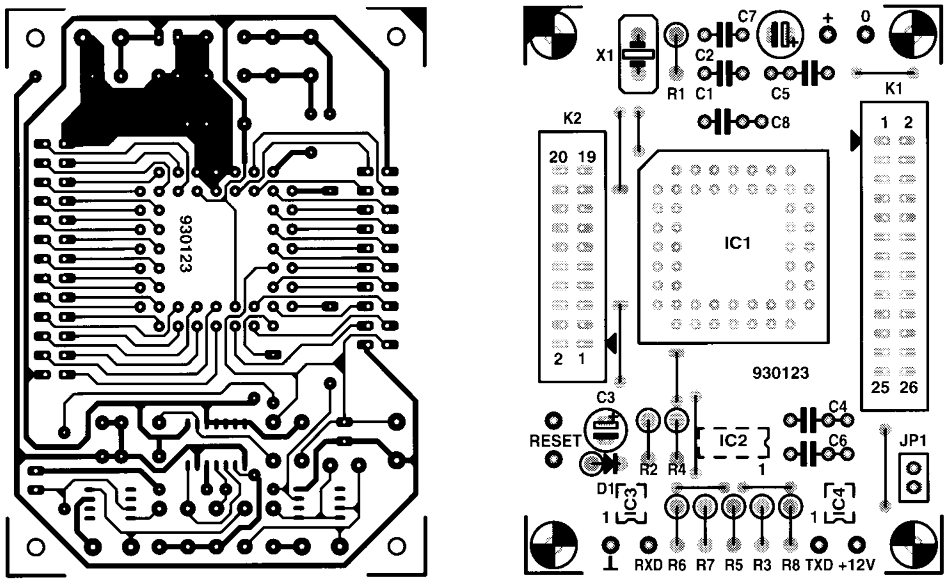


Fig. 3. Track layout (direct reading) and component mounting plan of the printed circuit board designed for the development system (PCB available ready-made through the Readers Services).

COMPONENTS LIST

Resistors:
R1 = 1MΩ5
R2;R5;R7 = 4kΩ7
R3;R4 = 100kΩ
R6 = 1kΩ5

Capacitors:
C1;C2 = 22pF
C3 = 1µF 16V radial
C4 = 330nF
C5;C6;C8 = 100nF
C7 = 22µF 16V radial

Semiconductors:
D1 = 1N4148
IC1 = 68HC11A1 (Motorola)
IC2 = 74HCT4066 (SMD)
IC3;IC4 = IL206 or IL207 (SMD)

Miscellaneous:
JP1 = 2-way pin header
K1 = 26-way boxheader
K2 = 20-way boxheader
X1 = 8MHz crystal
1 52-pin PLCC socket
8 PCB terminal pins
1 Printed circuit board 930123 (see page 70)

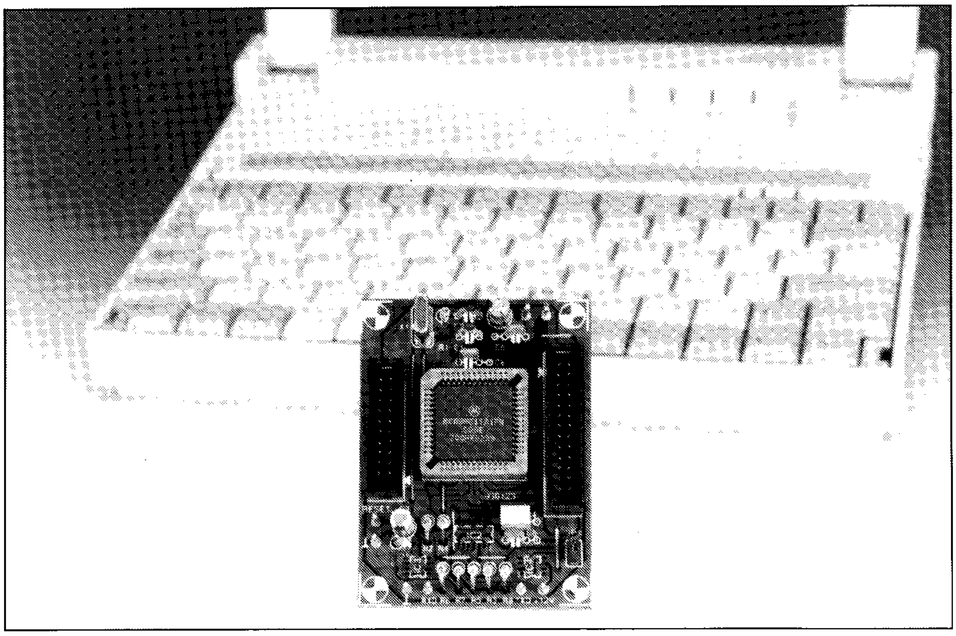


Fig. 4. Prototype of the processor board photographed in front of a portable MS-DOS PC used to download development software from Motorola's bulletin board, and to communicate with the 68HC11 board.

Lines 220 and 230 allow you to enter the desired baud rate, in this case, 1200. The last line which needs to be 'customized' is 1100. Replace the statement reading "T0% >100" with "T0% >5000".

If, after starting a program, an error report appears telling you that a WEND has been encountered without an associated WHILE, the WEND instruction in line 1100 must be moved to a new line.

Program development

If you have the hardware and the above utility programs, you can start developing programs for the 68HC11. Source code must be written in ASCII format, and comply with the rules given in the file ASMHC11.HLP. Connect the 68HC11 system to your PC's serial port via three wires, RxD, TxD and ground (note: in some cases, RxD and TxD must be swapped). Run E9CONFIG.BAS under QBASIC to set up the file exchange and EEPROM programming. If required, the mini debugger may be copied into the controller's RAM. Thanks to the bidirectional connection between the PC and the processor board, you get a very good idea of the operation of the application program, and the type of errors it may contain. ■

For further reading:

HC11 MC68HC11A8 databook.
AN1060 (application note) *MC68HC11 Bootstrap Mode.*
MC68HC11 programmer's reference manual.

The above publications are available from the Motorola European Literature Centre, 88 Tanners Drive, Blakelands, Milton Keynes MK14 5BP.

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March 1994

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February 1994

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January 1994

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* Delivery from week 10, 1994.

December 1993

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SAB80C535 datasheet	9.75

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80C535 HARDWARE/ASSEMBLER COURSE

PART 2: A-D CONVERTER AND WATCHDOG

Software by Dr. M. Ohsmann

Analogue-to-digital (A-D) converter

The analogue-to-digital converter contained in the 80C535 microcontroller is a complex unit. The structure is given in **Fig. 4**. The operation of the ADC is controlled via two special registers. The primary control register is located at address 0D8H, and is called ADCON. Bits 0, 1 and 2 in this register control the multiplexer connected ahead of the A-D converter proper. These bits determine which input line on port P6 is connected to the ADC input for the next conversion cycle. The ADC mode is controlled by bit 3 in the ADCON register. If the bit is set to 0, the ADC stops after each conversion. If the bit is set to 1, the ADC operates continuously.

Bit 4 in the ADCON register is a BUSY flag, which can only be read. When at 1, this bit indicates that a conversion is in progress. Shortly afterwards, it returns to 0. An A-D conversion lasts 14 machine cycles, or 14 µs at a CPU clock frequency of 12 MHz. Once the BUSY flag is at 0, the result of the A-D conversion may be read from an SFR called ADDAT at address 09DH.

The ADC has a resolution of 8 bits. A special feature of the 80C535 is the reference voltage selection, which makes the ADC a very flexible unit. The 80C535 requires an external reference voltage of 5 V, which is connected via pin 12 (VAGND, reference voltage ground terminal) and pin 11 (VAREF, reference voltage positive terminal). For the maximum values of the reference voltage, please refer to the description of the 80C535 single-board computer, and the SAB80C535 datasheets.

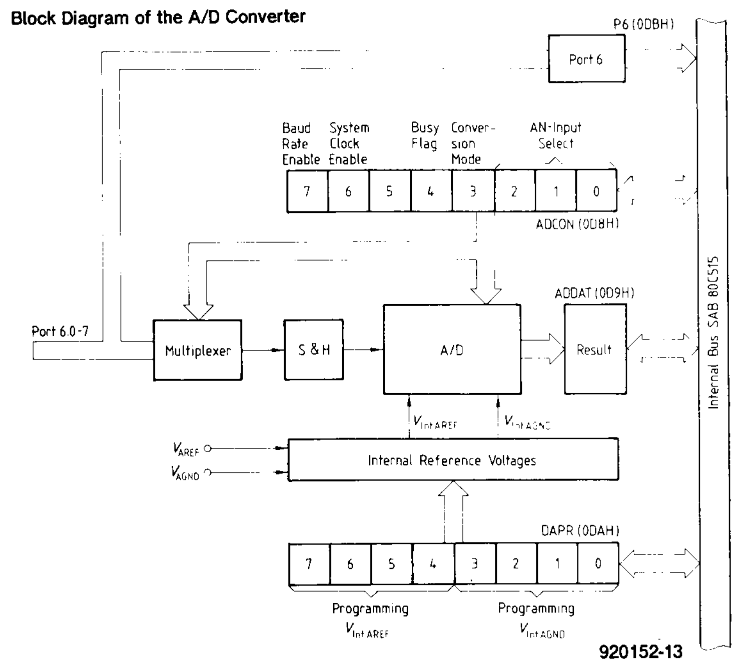

Fig. 3. Structure of the analogue-to-digital converter (ADC) contained in the 80C535.

For the experiments discussed in the present course, the SBC supply voltage (5 V) is used (as determined by jumpers JP3 and JP4), which means that no additional parts or external supplies are required. The internal reference voltage used by the ADC is derived from the external reference with the aid of a programmable voltage divider, which is controlled via an SFR called DAPR at address 0DAH. The lower nibble of DAPR (bits 0 through 3) allow the lower limit, IVAGND, of the voltage converter window to be programmed, while the higher nibble (bits 4 through 7) programs the upper limit, IVAREF, of the window in steps of (VAREF/VAGND)/16. The values listed in **Table 3** are obtained at VAGND=0 V and VAREF=5 V.

The conversion window must have a minimum 'size' of 1 V. A window size of 0-5 V is obtained by loading DAPR with the value 0000 0000B. Similarly, a value of 1000 0100B results in a window size of 1.25-2.5 V. The 8-bit ADC uses the window so created, and divides it into 256 parts. Assuming a window size of 0-5 V, a voltage of 2.5 V at the A-D converter produces an output value of 128, or 080H, in the ADDAT register. The same input voltage would produce a value 255, or 0FFH, if a window size of 1.25-2.5 V

IVAGND IVAREF	Bits 3 to 0 (IVAGND)	Bits 7 to 4 (IVAREF)
0	0000	—
0.3125	0001	—
0.625	0010	—
0.9375	0011	—
1.25	0100	0100
1.5625	0101	0101
1.875	0110	0110
2.1875	0111	0111
2.5	1000	1000
2.8125	1001	1001
3.125	1010	1010
4.4375	1011	1011
3.75	1100	1100
4.0625	—	1101
4.375	—	1110
4.68754	—	1111
5.0	—	0000

Table 3. ADC window size depending on IVAREF and IVAGND programming.

were defined. Interestingly, a 10-bit converter may be realized by setting up four windows with a size of 1.25-V each. This will be reverted to below.

An A-D conversion operation is started as follows. First, write the desired window size into DAPR. Next, the ADC converts the voltage level on the channel selected via ADCON. Meanwhile, the BUSY flag is set. The result of the conversion is available for reading as soon as the BUSY flag has returned to 0. Incidentally, it is possible to convert alternating voltages (of up to 5 kHz according to the datasheets), but only if the source impedance of the voltage source driving the ADC input is smaller than 5 kΩ. This is necessary to enable the charge contained in the internal capacitance of the ADC to be reversed within the so-called LOAD time of three machine cycles. The lines of port P6 (analogue input lines) may also be interrogated directly at address 0DBH (not bit-addressable). For example, if you need only two analogue inputs, you have six digital input lines left on P6.

Armed with the above knowledge, you should be able to understand the operation of the example program given at the end of the article on the 80C535 computer. A further example covering the use of the ADC in the 80C535 is discussed below.

A 10-bit A-D converter in software

The flow-chart of a program that turns the 8-bit ADC contained in the 80C535 into a 10-bit converter is given in **Fig. 5**, while the assembly language listing is shown in **Fig. 6**. The main program starts at the MAIN label. It switches the system clock on to port line P1.6 (this is done for test purposes), and sets variable Channel to 0. This variable contains the channel to be converted later by AD10BIT, the A-D converter subroutine proper. Next, the main program calls subroutine AD10BIT, which does the actual conversion, and stores the result into a

80C535 PROGRAMMING

You need the following to be able to follow the 80C535 hardware/assembler course:

Hardware:
- An 80C535 single-board computer as described in *Elektor Electronics* February 1994.
- An IBM PC or compatible with a serial port on COM1: or COM2:.

Software:
- Courseware disk (5.25 inch, 360K MSDOS format).
- EMON52 system EPROM, fitted on 80C535 SBC.

The courseware disk and EPROM are available as a set under order code **6221**. The disk is also available separately under order code 1811. For prices and ordering information, see page 70.

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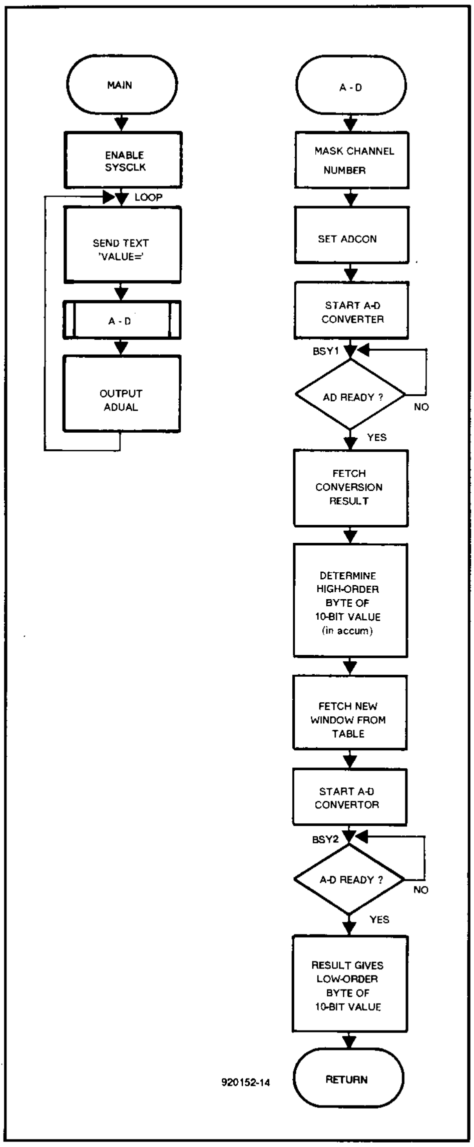


Fig. 5. Flow chart of 10-bit analogue-to-digital converter program.

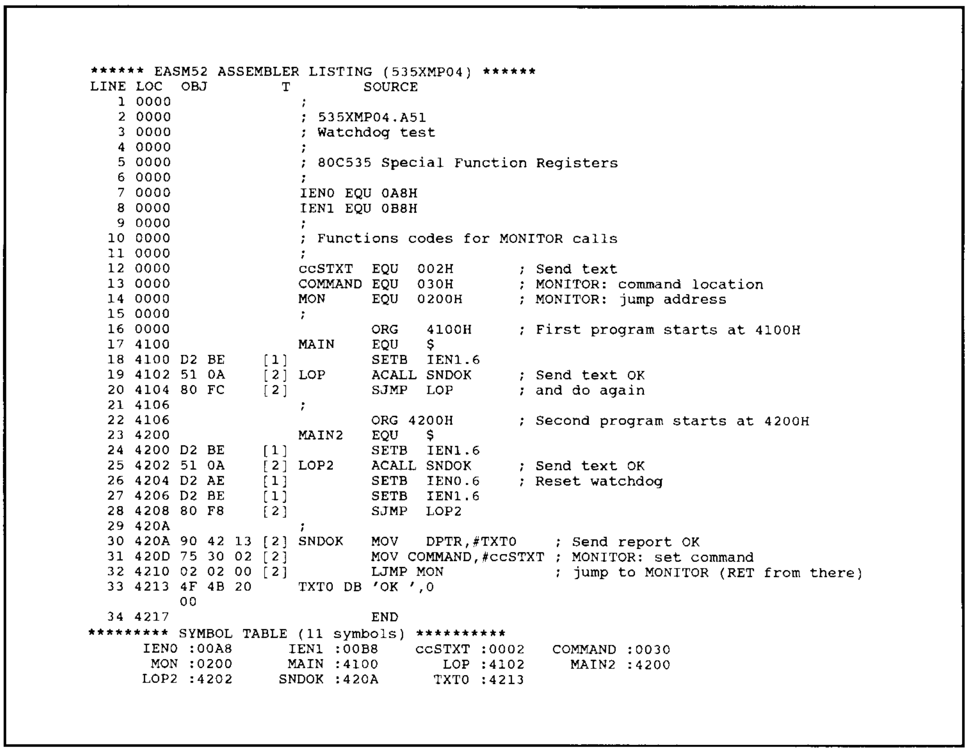
```
****** EASM52 ASSEMBLER LISTING (535XMP03) ******
LINE LOC  OBJ        T         SOURCE
   1 0000                 ;  535XMP03.A51
   2 0000                 ;  10 Bit A-D converter
   3 0000                 ;
   4 0000                 ;  80535 SFRs definition
   5 0000                 ;
   6 0000                 ADCON EQU 0D8H
   7 0000                 ADDAT EQU 0D9H
   8 0000                 DAPR  EQU 0DAH
   9 0000                 ;
  10 0000                 ;  Internal RAM definition
  11 0000                 ;
  12 0000                         ORG    050H              ; Start address in internal RAM
  13 0050                 Channel DS     1                 ; Channel number with AD conversion
  14 0051                 ADval   DS     2                 ; 10 bit measured AD value
  15 0053                 ;
  16 0053                         ORG    4100H             ; Program starts at 4100H
  17 4100 75 D8 40 [2] MAIN    MOV    ADCON,#01000000B ; Switch on SYSCLK on P1.6
  18 4103 75 50 00 [2]         MOV    Channel,#0
  19 4106 90 41 46 [2] LOOP    MOV    DPTR,#TXT2        ; Send text
  20 4109 31 4F    [2]         ACALL  STXT
  21 410B 12 41 18 [2]         LCALL  AD10BIT           ; 10 bit converter subroutine
  22 410E 78 51    [1]         MOV    R0,#ADval
  23 4110 75 30 05 [2]         MOV    COMMAND,#ccdRO16 ; Output ADval as decimal value
  24 4113 12 02 00 [2]         LCALL  MON
  25 4116 80 EE    [2]         SJMP LOOP
  26 4118                 ;
  27 4118 E5 50    [1] AD10BIT MOV   A,Channel         ; Fetch channel number
  28 411A 44 10    [1]         ORL   A,#00010000B      ; Mode: single conversion
  29 411C 54 3F    [1]         ANL   A,#00111111B
  30 411E F8       [1]         MOV   R0,A              ; Save
  31 411F E5 D8    [1]         MOV   A,ADCON           ; Fetch old mode word
  32 4121 54 C0    [1]         ANL   A,#11000000B      ; Reset AD part
  33 4123 48       [1]         ORL   A,R0              ; And set anew
  34 4124 F5 D8    [1]         MOV   ADCON,A           ; And set as mode
  35 4126 75 DA 00 [2]         MOV   DAPR,#0           ; Start conversion 0-5.0 volt
  36 4129 20 DC FD [2] BSY1    JB    ADCON.4,BSY1      ; Wait until ready
  37 412C E5 D9    [1]         MOV   A,ADDAT           ; Fetch result
  38 412E 23       [1]         RL    A                 ; Shift high-order bits to
  39 412F 23       [1]         RL    A                 ; low-order bits
  40 4130 54 03    [1]         ANL   A,#3              ; Two most significant bits
  41 4132 F5 52    [1]         MOV   ADval+1,A         ; Store most significant byte of 10 bits
  42 4134 90 41 42 [2]         MOV   DPTR,#TABLE1      ; and use as table offset
  43 4137 93       [2]         MOVC  A,@A+DPTR         ; Fetch new AD converter range
  44 4138 F5 DA    [1]         MOV   DAPR,A            ; Start conversion
  45 413A 20 DC FD [2] BSY2    JB    ADCON.4,BSY2      ; Wait until ready
  46 413D E5 D9    [1]         MOV   A,ADDAT           ; Fetch result
  47 413F F5 51    [1]         MOV   ADval+0,A         ; is low-order byte of 10 bit value
  48 4141 22       [2]         RET
  49 4142                 ;
  50 4142 40              TABLE1  DB  01000000B  ; 0.00 - 1.25 Volt
  51 4143 84                      DB  10000100B  ; 1.25 - 2.50 Volt
  52 4144 C8                      DB  11001000B  ; 2.50 - 3.75 Volt
  53 4145 0C                      DB  00001100B  ; 3.75 - 5.00 Volt
  54 4146                 ;
  55 4146 0D 0A 56        TXT2    DB      13,10,'Value=',0
          61 6C 75
          65 3D 00
  56 414F                 ;
  57 414F                 ; Function-codes etc. for MONITOR calls
  58 414F                 ;
  59 414F                 ccSTXT  EQU  002H                   ; send text
  60 414F                 ccdRO16 EQU  005H                   ; send 16 bit value @R0 decimal
  61 414F                 COMMAND EQU  030H                   ; MONITOR: command location
  62 414F                 MON     EQU  0200H                  ; MONITOR: jump address
  63 414F                 ;
  64 414F 75 30 02 [2] STXT    MOV COMMAND,#ccSTXT   ; MONITOR: set command
  65 4152 02 02 00 [2]         LJMP MON              ; jump to MONITOR (RET from there)
  66 4155                         END
********* SYMBOL TABLE (17 symbols) **********
     ADCON :00D8     ADDAT :00D9      DAPR :00DA   Channel :0050
     ADval :0051      MAIN :4100      LOOP :4106   AD10BIT :4118
      BSY1 :4129      BSY2 :413A    TABLE1 :4142      TXT2 :4146
    ccSTXT :0002   ccdRO16 :0005   COMMAND :0030       MON :0200
      STXT :414F
```

Fig. 6. By means of a clever division of the internal reference voltage into four sub-ranges, this program implements a 10-bit A-D converter (535XMP03 on course diskette).

16-bit variable called Adval, located in the internal RAM of the 80C535. The conversion result is output in decimal notation by the main program via the 16-bit decimal output subroutine in the EMON52 monitor. Once that is done, the main program starts again (at LOOP), and continues infinitely.

In subroutine AD10BIT, the ADC is first switched to single conversion mode, and to the channel indicated by the respective variable. When programming the ADC mode and channel number, care should be taken to mask bits 6 and 7 which control the baudrate generator and the system clock output. This is achieved by first fetching the contents of ADCON (line 31), and then changing the desired bits only with the aid of ORL and AND instructions. Next, the ADC (with a window size of 0-5 V) is started by the instruction in line 35. The loop in line 36 waits for the conversion operation to finish by constantly monitoring the BUSY bit. Once the conversion is done, the result is fetched. Bits 6 and 7 of the result indicate one of four ranges in which the input voltage lies. The four ranges are 0-1.25 V, 1.25-2.5 V, 2.5-3.75 V and 3.75-5 V. Two rotate instructions move these two bits to positions 0 and 1 in the accumulator. The word so created forms the higher order byte of the total result, and is stored at address ADval+1. Next, the A-D conversion is started using the relevant window. The control words to be loaded into DAPR for this purpose are contained in a look-up table (label: TABLE1). The two bits already established are used as indices for access to the table (lines 42 and 43). The second, 'fine', A-D conversion is started in line 44, and BUSY is monitored as before to wait for the conversion to finish. The result yields the lower-order byte of the total result, and is stored at address ADval+0. That completes the full 10-bit conversion.

The program processes the voltage at analogue input 0 (K6 pin 3), and outputs the voltage level as a decimal value via the V24 serial channel to the PC. Clearly, the A-D converter described is only suitable for very slowly varying voltages, since two conversions are performed, during which the input voltage must remain the same. Tests on several 80C535 controllers have shown that the internal ADC is subject to fairly large tolerances. For example, even a direct connection of the analogue input to VAREF failed to produce the full-scale value of 1023. Instead, a lower value was obtained, which also appeared to vary between the chips tested. For applications demanding high accuracy, it is, therefore, better to use an external converter.



```
****** EASM52 ASSEMBLER LISTING (535XMP04) ******
LINE LOC  OBJ        T        SOURCE
   1 0000                 ;
   2 0000                 ; 535XMP04.A51
   3 0000                 ; Watchdog test
   4 0000                 ;
   5 0000                 ; 80C535 Special Function Registers
   6 0000                 ;
   7 0000                 IEN0 EQU 0A8H
   8 0000                 IEN1 EQU 0B8H
   9 0000                 ;
  10 0000                 ; Functions codes for MONITOR calls
  11 0000                 ;
  12 0000                 ccSTXT  EQU  002H       ; Send text
  13 0000                 COMMAND EQU  030H       ; MONITOR: command location
  14 0000                 MON     EQU  0200H      ; MONITOR: jump address
  15 0000                 ;
  16 0000                         ORG   4100H     ; First program starts at 4100H
  17 4100                 MAIN    EQU   $
  18 4100 D2 BE     [1]           SETB  IEN1.6
  19 4102 51 0A     [2] LOP       ACALL SNDOK     ; Send text OK
  20 4104 80 FC     [2]           SJMP  LOP       ; and do again
  21 4106                 ;
  22 4106                         ORG 4200H       ; Second program starts at 4200H
  23 4200                 MAIN2   EQU   $
  24 4200 D2 BE     [1]           SETB  IEN1.6
  25 4202 51 0A     [2] LOP2      ACALL SNDOK     ; Send text OK
  26 4204 D2 AE     [1]           SETB  IEN0.6    ; Reset watchdog
  27 4206 D2 BE     [1]           SETB  IEN1.6
  28 4208 80 F8     [2]           SJMP  LOP2
  29 420A                 ;
  30 420A 90 42 13 [2] SNDOK     MOV   DPTR,#TXT0    ; Send report OK
  31 420D 75 30 02 [2]           MOV COMMAND,#ccSTXT ; MONITOR: set command
  32 4210 02 02 00 [2]           LJMP MON            ; jump to MONITOR (RET from there)
  33 4213 4F 4B 20      TXT0 DB 'OK ',0
          00
  34 4217                         END
********* SYMBOL TABLE (11 symbols) **********
      IEN0 :00A8      IEN1 :00B8    ccSTXT :0002   COMMAND :0030
       MON :0200      MAIN :4100       LOP :4102     MAIN2 :4200
      LOP2 :4202     SNDOK :420A      TXT0 :4213
```

Fig. 4. Program 535XMP04 on your course disk teaches you the basics of the 80C535's watchdog.

Watchdog

To enable uninterruptable systems (also called no-break systems) to be realized more comfortably, the 80C535 features an on-board watchdog timer. This is basically a 16-bit counter which generates a processor reset if an overflow occurs. The watchdog is started by setting bit 6 in the IEN1 SFR at address 0B8H. Once started by software, the watchdog can not be halted. At a clock frequency of 12 MHz, a CPU reset is generated after 65,536 µs. Obviously, that can only be prevented by the program resetting the watchdog timer to 0 in time. This is achieved by setting bit 6 in IEN0 and bit 6 in IEN1 by two successive (!) instructions.

A correctly operating program must always ensure that the watchdog is reset in time. Once the program crashes, it is likely that the watchdog is no longer reset. The result is that the entire CPU is reset by the watchdog, and the program is automatically restarted. It is possible to use software to determine whether or not a reset was triggered by the watchdog by examining bit 6 in the IP0 register (address 09AH, not bit-addressable). if this bit is at 1, the CPU was reset by the watchdog.

The use of the watchdog in 80C535 assembly language is illustrated by the listing in **Fig. 7**. This program, 535XMP04.A51 (found on your course disk), shows a 'faulty' subprogram which does not reset the watchdog, and starts at address 4100H. A correctly working program starts at address 4200H.

What happens if the program at 4100H is started after a reset caused by the watchdog? Care should be taken not to reset the watchdog by a periodically actuated interrupt routine. That is because the correctness of the interrupt routine is no guarantee that the main program is still running correctly. Implementing a truly 'no-break' system is quite taxing to the programmer!.

What happens when the quartz crystal oscillator fails? No provision has been made in the 80C535 to detect this, and for the highest possible reliability it is, therefore, recommended to employ an external watchdog. The 80C537 has a few interesting features in this respect.

Next time: The 80C535's timers and their use in time measurement and pulsewidth modulation. Also a brief introduction into the use of interrupts.

Note: in response to readers' enquiries we would suggest the following suppliers of the SAB80C535 microcontroller:

- » Electrovalue, Unit 3, Central Trading Estate, Staines TW18 4UX, England. Tel. (0784) 442253, fax (0784) 460320.
- » C-I Electronics, P.O. Box 22089, 6360-AB Nuth, Holland. Fax: (+31) 45 241877 (IC supplied incl. free datasheet).

C-I Electronics also supply kits of the 80C535 computer. *tech. ed.*

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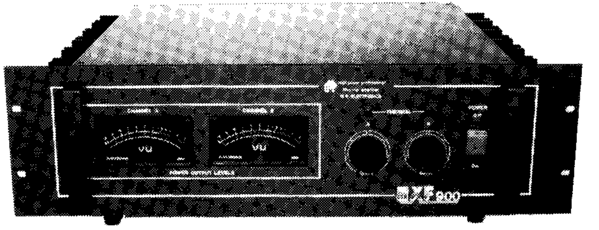

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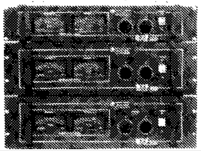

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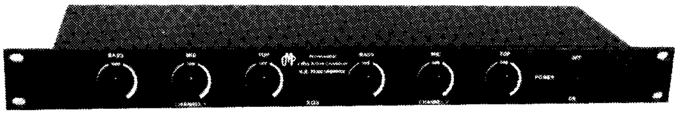

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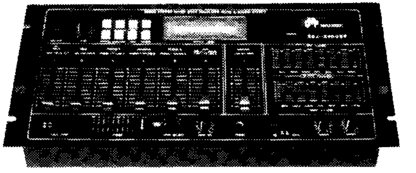

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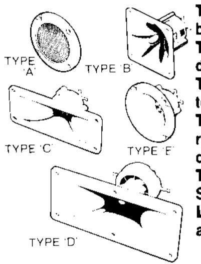

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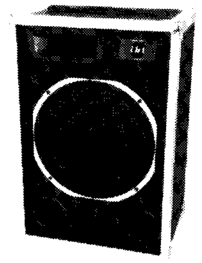

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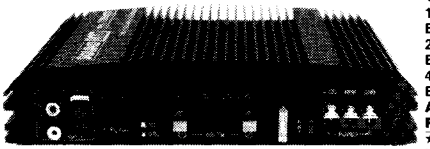

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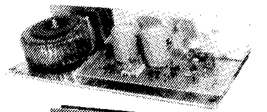

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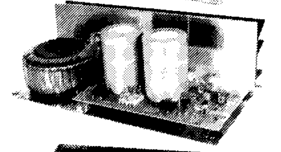

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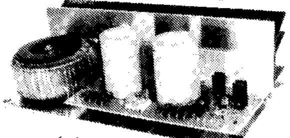

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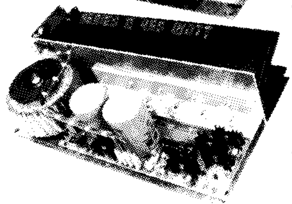

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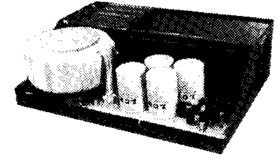

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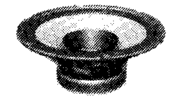

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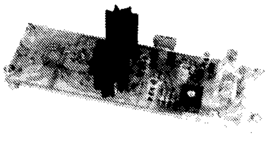

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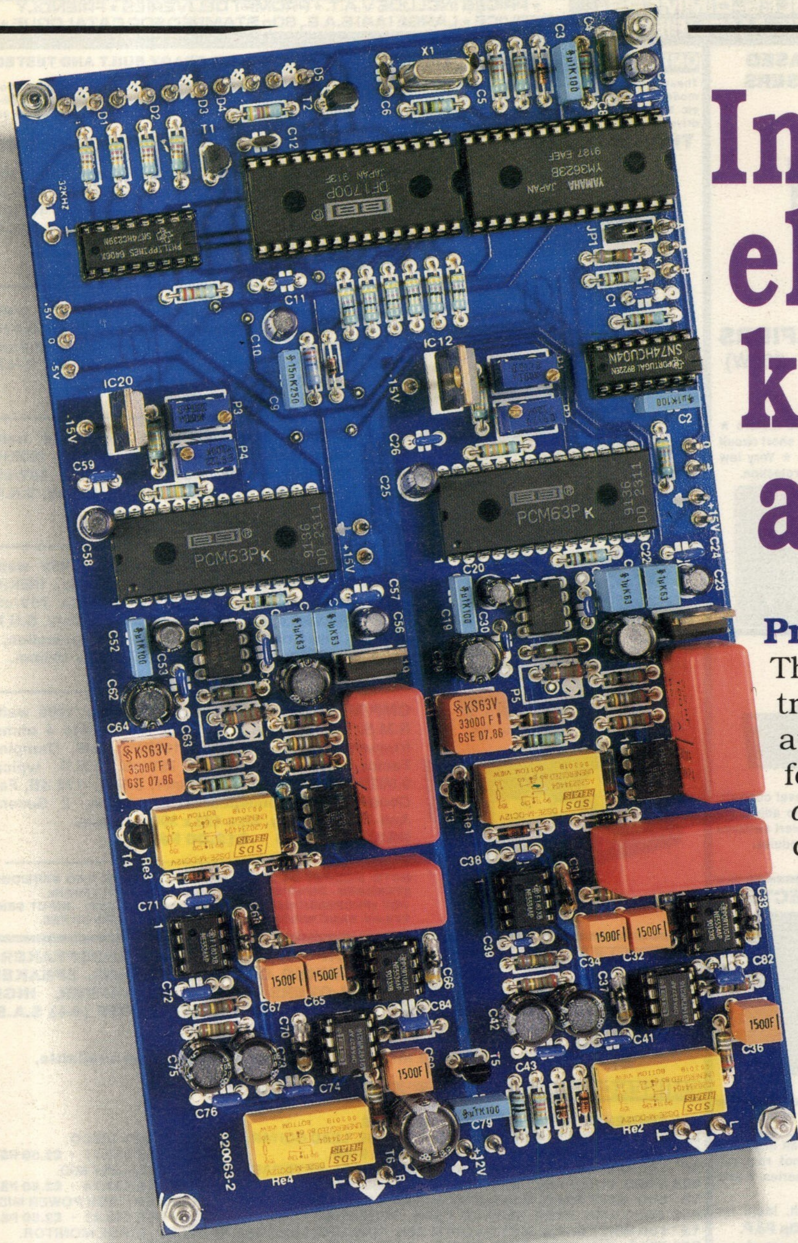

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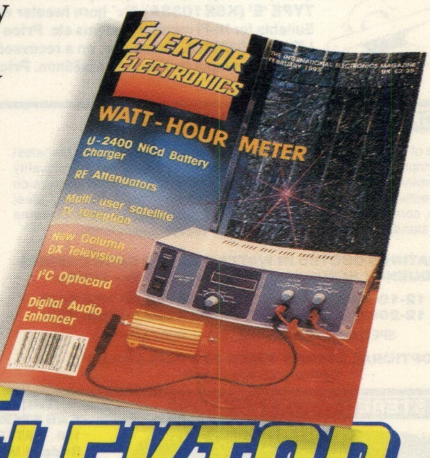
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c)	computers	☐	☐	☐
d)	test & measurement	☐	☐	☐
e)	audio & hi-fi	☐	☐	☐
f)	physics	☐	☐	☐
g)	general science	☐	☐	☐
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12	Electronics scene (news)	☐	☐	☐
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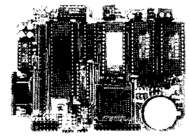

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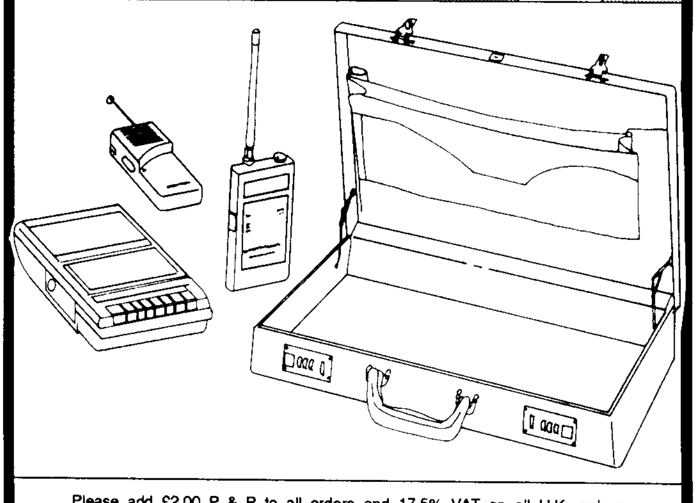

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VISA

MAINS SIGNALLING SYSTEM

PART 1: RECEIVER

Design by W. Hackländer & S. Furchtbar

Mains signalling is a method by which signals can be superimposed on mains wiring for the remote control of electrical equipment. It was first proposed by two Swiss inventors, Routin and Brown, who patented the method to control street lighting in 1896. The technique is well established and accepted in the USA, but in this country and Europe interest in it as a medium for communication has begun only in the late 1980s. This article deals with a system for use in home automation. The main advantages of the system are ease of installation, flexibility and relatively low cost (because it uses existing mains wiring.

The mains signalling system, which is controlled by a computer (**not** part of the system), may be used for switching or dimming lights, random switching of lights to give the house a 'lived-in' look while the occupant is away, switching all lights simultaneously in the event of danger, providing programmed or remote switching of electrical appliances, and many others. It is particularly helpful to disabled or handicapped people.

The system uses radio frequency (r.f.) signals superimposed on the very low frequency (v.l.f.) mains voltage. The r.f. signals are too high in frequency to interfere with the power supply and too low to affect radio and TV reception. They are, however, easily detected by a suitable receiver as described in this first part of the article. The modulation used is amplitude shift keying (ASK) which is facilitated by an IC specially developed for mains signalling systems.

The equipment complies with European Standard EN 50 065-1, which was approved by CENELEC (Comité Européen de Normalisation Electrotechnique—European Committee for Electrotechnical Standardization), of which the United Kingdom is a member.*

The system forms a link between a computer and mains-operated equipment—see **Fig. 1**. It consists of a transmitter (sometimes called controller) and one or more receivers. Each apparatus to be controlled via the system needs its own receiver, which switches it on and off. Up to 127 receivers may be controlled by one transmitter. The status of each receiver is monitored at the transmitter. The transmitter is an intelligent unit whose microprocessor provides the commands that are transmitted via the computer. Communication between the transmitter and the computer is via a standard RS232 link.

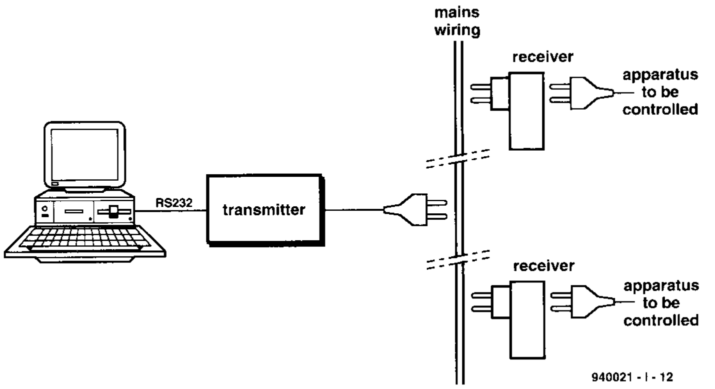

Fig. 1. Setup of a 2-receiver system. Up to 127 receivers may be accommodated.

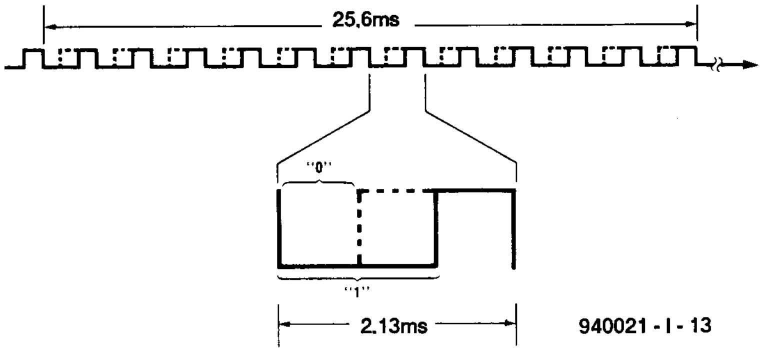

Fig. 2. Construction of the code used by the MM53200N.

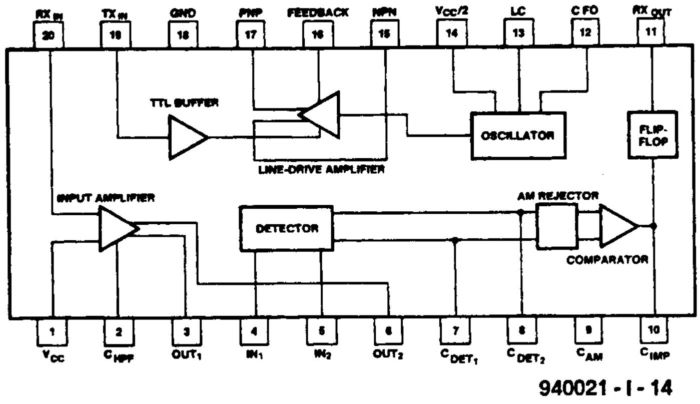

Fig. 3. Block schematic of modem IC NE5050.

Design considerations

The circuit diagram in **Fig. 4** is drawn in two distinct parts: that at the left per-

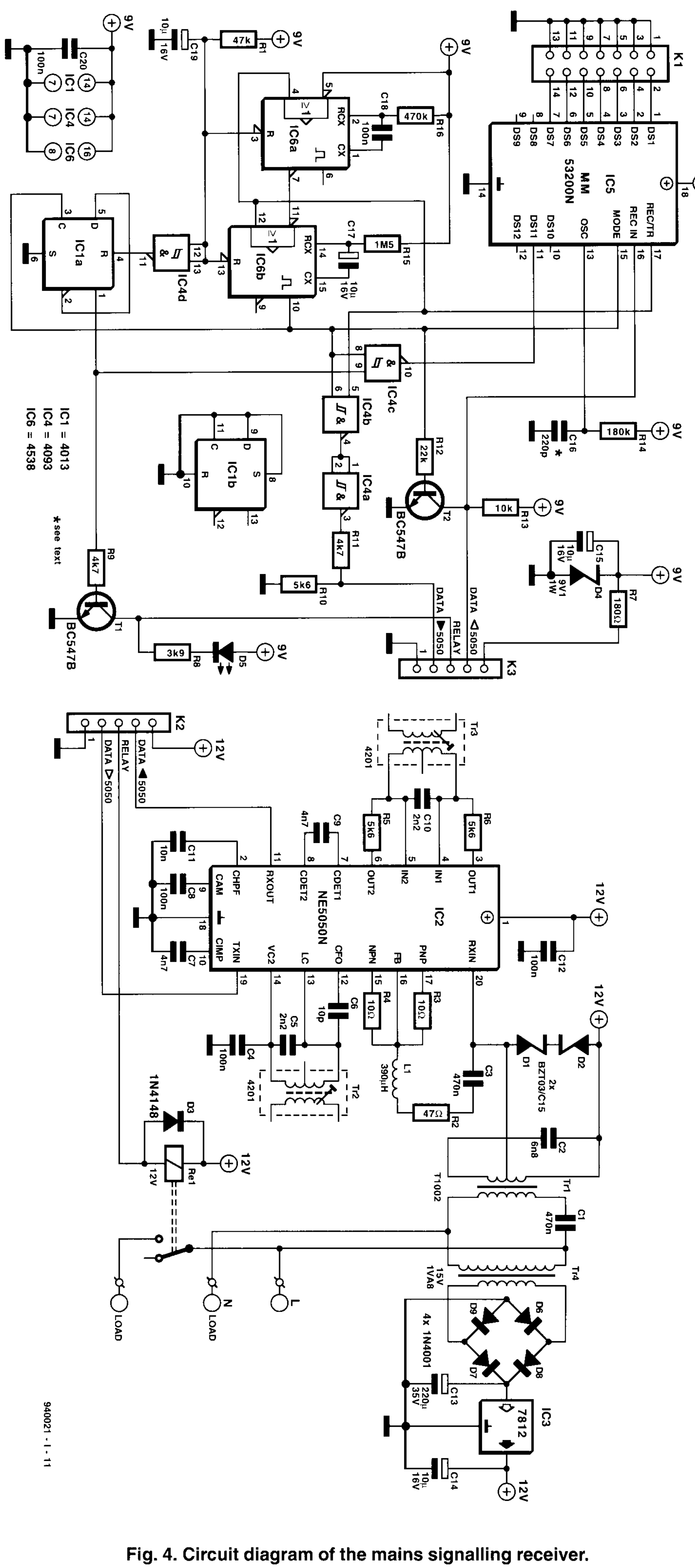

Fig. 4. Circuit diagram of the mains signalling receiver.

forms the data recognition and back reporting of data information; that at the right comprises the modulator/demodulator—modem— and the power supply.

The transmitter sends a train of 13 pulses along the mains wiring which are picked up by the receiver(s). Of the 13 pulses, eight are used for conveying the address. Each receiver compares the incoming code with its own address. If the two are identical, the relay in the receiver changes state. At the same time, the receiver sends back a pulse train containing its address and possibly having a '1' in the 11th position. This digit indicates to the transmitter that the receiver's relay is energized. This arrangement means that each receiver occupies two addresses in the system. Since eight bits are used, the total number of receivers is limited to 127, which should not present a problem in most cases.

Address recognition is performed by IC$_1$, a Type MM53200 from National Semiconductor. This IC contains an oscillator, an encoder and a decoder. In the transmit mode, the IC converts the 12 logic levels at its data inputs, DS$_1$–DS$_{12}$, into a trains of 12 pulses (plus a start pulse). The pulse repetition rate (p.r.r.) is determined by network R$_{14}$-C$_{16}$. The width of each pulse determines the logic level—see **Fig. 2**. The encoding used guarantees reliable data transfer even when the signal lines are subject to interference.

In the receive mode, the incoming signal (12 data pulses plus start pulse) is compared to the local code in a sequential manner. If there is an error, the system is reset and begins its comparison on the next pulse. If all 12 bits are received correctly, a 'valid' signal is generated. This signal clears one counter and clocks another. The latter (3-stage) counter counts the 'valid' pulses. When and only when four correct pulse trains, with a maximum pulse spacing of 142 ms,have been received, does the transmit/receive output go low.

Data-select pins 1–9 of IC$_1$ are connected to ground via jumpers on header K$_1$. In the IC, the pins are connected to pull-up resistors, ensuring that each of them is automatically at high logic level if there is no jumper to earth. Consequently, the jumpers ate these pins enable addresses 0–127 to be set. Address 0 corresponds to no jumpers and address 127 to seven jumpers at K$_1$.

The clock of IC$_1$ has been fixed at about 45 kHz by the time-constant R$_{14}$-C$_{16}$. At that frequency, transmitting a complete pulse train takes about 25.6 ms.

When the power is switched on, monostables IC$_{6a}$ and IC$_{6b}$, as well as bistable IC$_{4d}$, are reset via R$_1$-C$_{119}$. The output of IC$_{6b}$ is then low, so that IC$_1$ is in the receive mode (via mode input pin 15). In this situation, T$_2$ is cut off, so that the signals from the modem section are transferred to pin 16 of IC$_1$. Pin 1 of bistable IC$_{1a}$ is low, so that T$_1$ is cut off and there is no supply to the relay. Diode D_1 is off.

When four times the correct code has been received, the transmit/receive output goes low. If no more valid data are received, this output changes state, which causes IC_{6a} and IC_{6b} to be triggered. The output of IC_{6b} clocks bistable IC_{1a}, causing this stage to change state. This results in T_1 being switched on, so that the relay is energized. Also, D_1 lights. The mono period of IC_{6a} is very short. Since the inverting output of this multivibrator is linked to the trigger input of IC_{6b}, that stage will no longer react to new incoming trigger pulses (it will also not be triggered by the data which the receiver is about to send back).

At the instant IC_{1a} changes state, IC_{6b} reverses the level at pin 15 of IC_1, which results in the IC sending its own address code. Gate (NAND) IC_{4c} provides the logic level for DS11 (pin 11). When the output of IC_{6b} is high, the output of the gate depends on the output state of IC_{1a} and thus on the status of the relay. If the gate provides a '0', the relay is energized; if a '1', the relay is not powered. In this way, the transmitter receives information as to the status of the receiver.

The pulse train from IC_1 is generated a few times until the mono time of IC_{1b} has elapsed. During this time, T_2 is on so that no transmitted signals can be sent back to pin 16 of IC_1. After this period, IC_1 switches back to the receive mode.

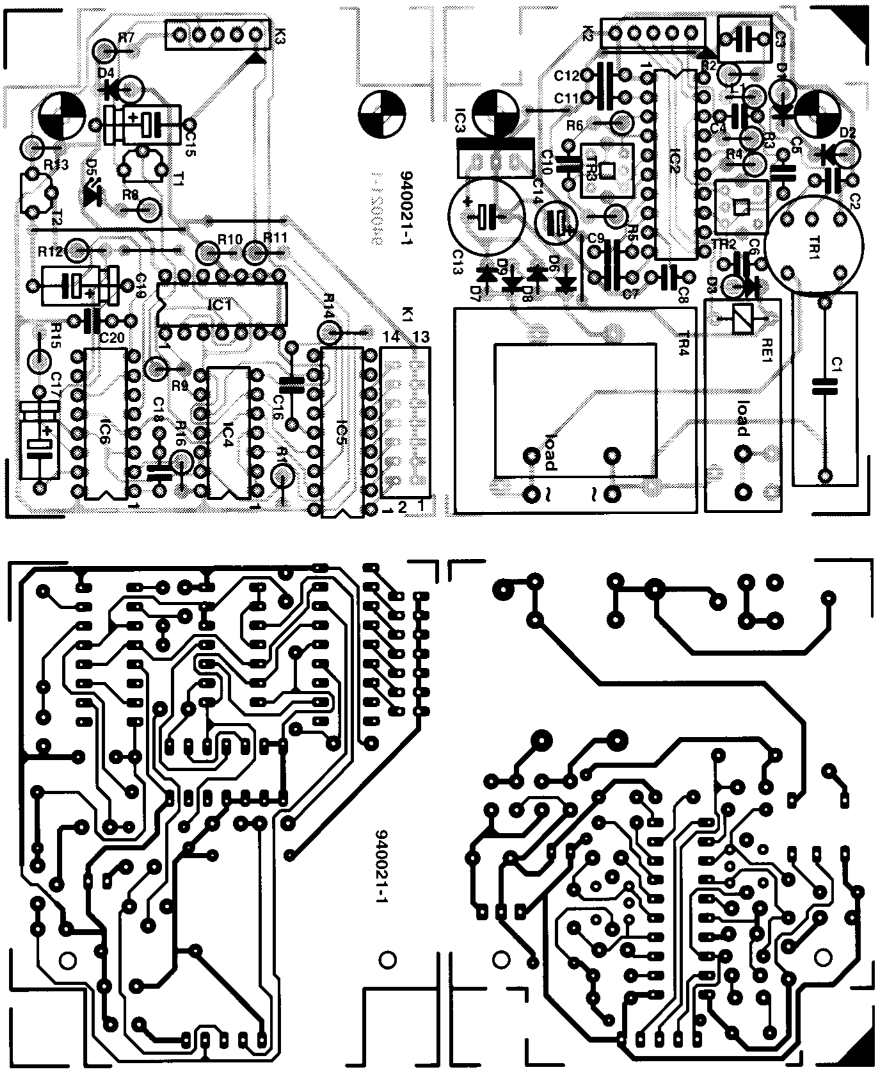

Fig. 5. Printed circuit board for the mains signalling receiver.

Modulation/demodulation

Modulation and demodulation of the digital signals is provided by line driver IC_2, a Type NE5050 from Philips/Signetics specially developed for use in mains signal-ling systems. The block diagram of this device is shown in **Fig. 3**. The IC uses amplitude shift keying in which the two digital levels are transmitted at different amplitudes (strictly speaking, maximum amplitude and no amplitude).

Capacitors C_5, C_6 and transformer Tr_2 determine the frequency of the send oscillator (here, 100 kHz). The carrier wave

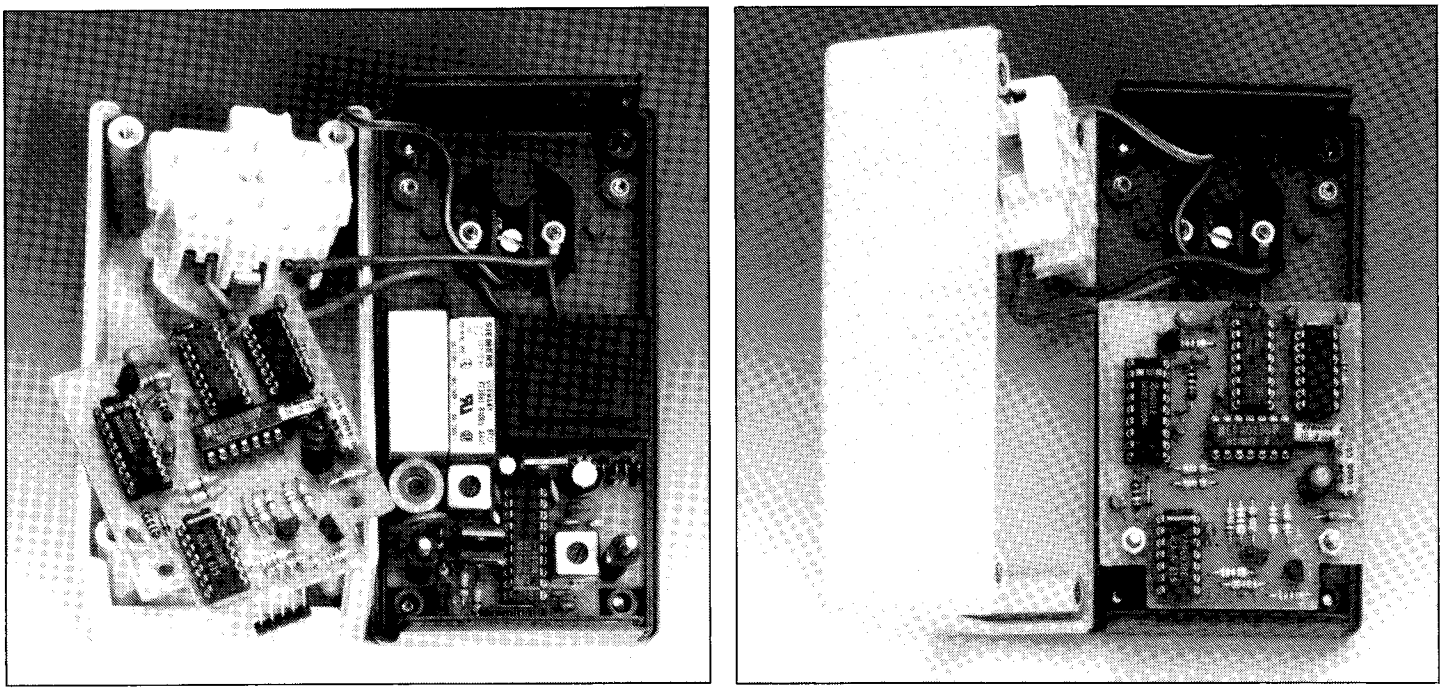

Fig. 6. Illustration of how the board should be fitted into the enclosure: first fit the modem board to the bottom of the case with threaded (or partly threaded) spacers (left-hand photo); then fit the digital board on top of the spacers (right-hand photo).

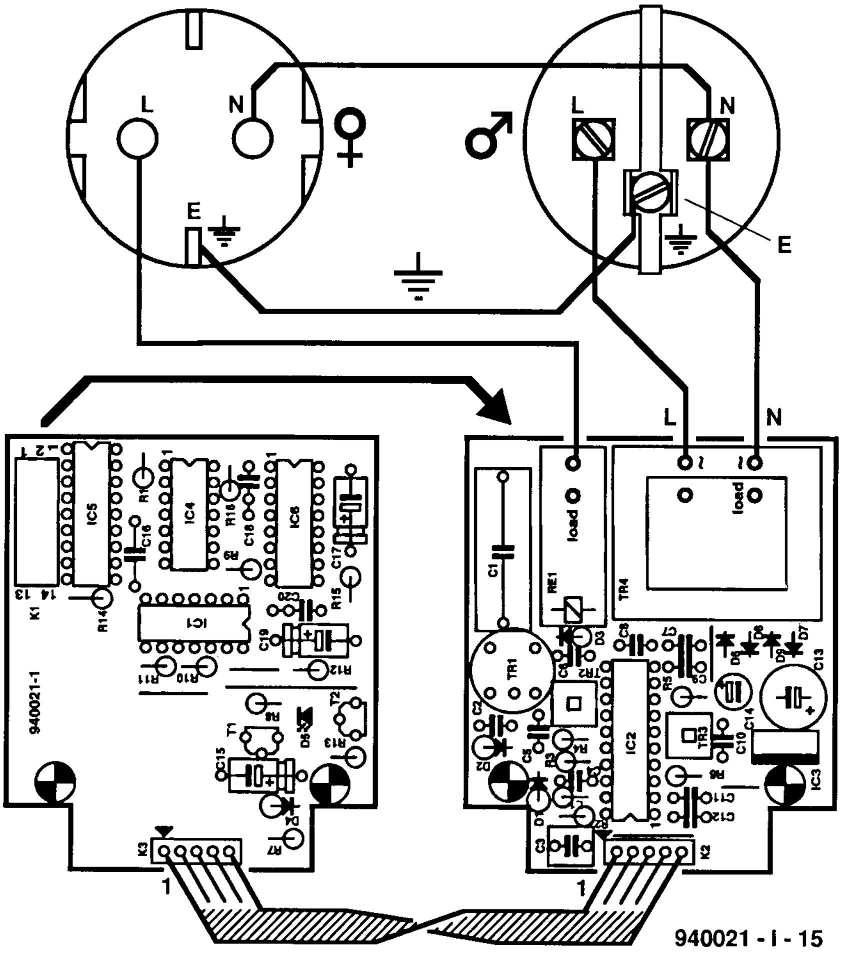

Fig. 7. Wiring diagram of the boards and plug and socket arrangement.

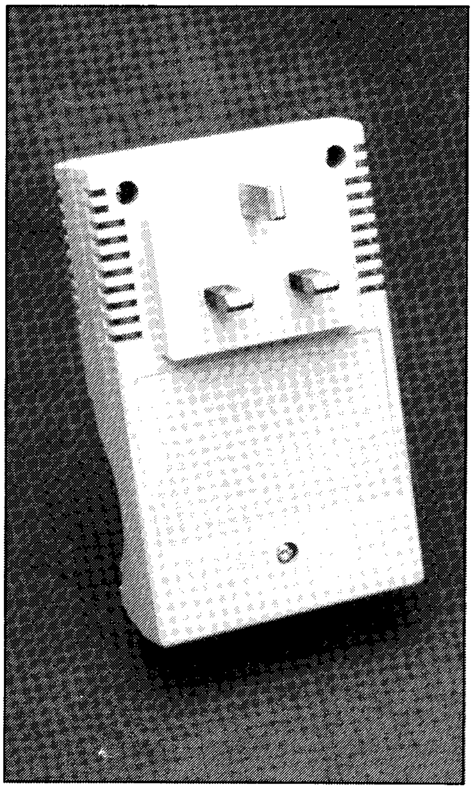

Fig. 8. Case fitted with standard UK plug and socket.

generated by the line driver is switched on and off by the digital signal applied to its pin 19. The output, pins 15 and 17, of IC_2 is applied to the mains wiring via R_3, R_4, low-pass filter L_1 (which suppresses high harmonics), impedance matching resistor R_2, coupling capacitor C_3 and isolating transformer Tr_1.

Capacitor C_2 and Tr_1 form a band-pass filter with a central frequency of about 110 kHz.

Capacitor C_1 provides severe attenuation of the 50 Hz mains signal.

Series-connected diodes D_1 and D_2 limit the received signal and suppress interfering spikes on the mains voltage. The specified types are special transient-voltage-suppression diodes that react very fast to such spikes: they should not be replaced by different types.

The received (and possibly limited) signal is applied to pin 20 and then to a band-pass filter in the IC, whose upper cut-off frequency is fixed at 300 kHz; the lower cut-off frequency is determined by the value of C_{11}.

A further band-pass filter, consisting of C_{10} and Tr_3, is provided between the input amplifier and the detector (in IC_2).

The signal is then applied to a low-pass filter of which C_9 is a part, and finally to an AM rejection stage, where any residual component of the 110 kHz carrier wave is removed. The average direct voltage is stored in C_8.

After passing through the comparator, the signal is enhanced by C_7 (which removes any remaining spikes) and an internal bistable (which smooths its edges). Finally, the data are sent to IC_{11} via pin 11.

The power supply is straightforward. A 1.8 VA transformer, Tr_4 provides 15 V a.c. which, after rectification in D_6–D_9 and smoothing by C_{13}, is held at 12 V by IC_3.

Since IC_1, IC_4, and IC_6 can not tolerate a 12 V supply, network R_7-D_4 lowers the supply to these ICs to 9 V.

Construction

The receiver must be built in a special, high-impact ABS enclosure with an integral mains plug at the front and a mains socket at the back; the type of plug and socket depends on the country you live in. The photograph in **Fig. 8** shows a standard UK type; American and European types are also available (see Parts List). The insulating properties of the enclosure must be first class, because transformer Tr_1 may not provide full mains isolation.

The circuitry is built on two printed circuit boards as shown in **Fig. 5**. One of these houses the modem IC, transformers and relay and the other the digital circuits. Remove two corners of each of the boards to ensure that the lid will still fit on the case.

Because of the limited available space, mount all resistors and zener diodes upright. Use sockets for all ICs.

Keep all connecting wires at the track side of the digital board short, otherwise the finished board will not fit in the case.

Place the LED a few millimetres above the board, so that it fits nicely in a 5 mm dia. hole drilled in the lid of the case. For safety reasons, **do not** use a 3 mm LED.

The two boards are interconnected via a length of 5-core flat-cable. Insert this cable in the holes at the track side of the upper board.

Solder three pins at the track side of the modem board for connecting the mains cable. In the prototype, flat pins with small ridges that sit securely on the board were used. However, standard round pins bent at right angles and securely soldered in place may also be used.

Interconnect the two mains connections in the case with the relevant pins underneath the mains transformer on the modem board with insulated circuit wire (5–10 cm long) terminated into appropriately sized solder tags. Connect the remaining pin underneath the relay with the L(ive) pin of the case socket. Interlink the earth terminals on the plug and socket. All these connections are shown in **Fig. 7**. Fit all mains connections on the boards

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with insulating sleeve.

When the boards are completed, install the modem board at the bottom of the case and fasten it with two 25 mm (1 in.) partly threaded spacers. Next, mount the other board on to the spacers and fix it into place with two M3 bolts. This board should be seated immediately above the relay. If necessary, fit shims on to the spacers to increase the distance between the board and relay slightly. The photographs in **Fig. 6** show how the boards are located in the case.

Parts list

Resistors:
R_1 = 47 kΩ
R_2 = 47 Ω
R_3, R_4 = 10 Ω
R_5, R_6, R_{10} = 5.6 kΩ
R_7 = 180 Ω
R_8 = 3.9 kΩ
R_9, R_{11} = 4.7 kΩ
R_{12} = 22 kΩ
R_{13} = 10 kΩ
R_{14} = 180 kΩ
R_{15} = 1.5 MΩ
R_{16} = 470 kΩ

Capacitors:
C_1 = 470 nF, 250 V a.c., 630 V d.c.
C_2 = 6.8 nF, MKT, pitch 5 mm
C_3 = 470 nF, MKT, pitch 5 mm
C_4, C_8, C_{12}, C_{18}, C_{20} = 100 nF, MKT, pitch 5 mm
C_5, C_{10} = 2.2 nF, MKT, pitch 5 mm
C_6 = 10 pF
C_7 = 4.7 nF, MKT, pitch 5 mm
C_9 = 4.7 nF
C_{11} = 10 nF
C_{13} = 220 µF, 35 V, radial
C_{14} = 10 µF, 16 V, radial
C_{15}, C_{17}, C_{19} = 10 µF, 16 V
C_{16} = 220 pF, polystyrene

Inductors:
L_1 = 390 µH

Semiconductors:
D_1, D_2 = BZT03/C15 (Philips)
D_3 = 1N4148
D_4 = zener, 9.1 V, 1 W
D_5 = LED, red, 5 mm
D_6–D_9 = 1N4001
T_1, T_2 = BC547B

Integrated circuits:
IC_1 = 4013
IC_2 = NE5050N (Philips/Signetics)
IC_3 = 7812
IC_4 = 4093
IC_5 = MM53200N (National Semiconductor)
IC_6 = 4538

Miscellaneous:
K_1 = 14-way header
K_2, K_3 = 5-core flatcable (5–10 cm)
Re_1 = relay, 12 V, 1 make contact, for PCB mounting
Tr_1 = T1002 (Toko 707VXT1002N)
Tr_2, Tr_3 = 4201 (Toko LPCS4201)
Tr_4 = mains transformer, 15 V, 1.8 VA for PCB mounting
Enclosure, 120×65×60 mm (approx) with integral plug and socket (see text). Suitable cases to UK, USA and European standards are available from Bopla (in UK represented by Phoenix Mecano Ltd, Telephone (0296) 398 853.
PCB, Ref. 940021-1 (see page 70)

*Further information on the general aspects of mains signalling may be obtained from the BEAMA Interactive and Mains Systems Association, Leicester House, 8 Leicester Street, London WC2H 7BN. Telephone 071 437 0678. Fax 071 437 4901.

In general, for domestic applications, the level of the signal signal applied across the mains wiring must not exceed 116 dB µV (631 mV). Measured across the line or neutral terminal and ground, the level must not exceed 316 mV (110 dB µV). The specified impedance must be 50 Ω.

Third harmonic spurious radiations must not exceed 57 dB µV (0.7 mV).

EN 50 065-1 specifies a frequency range of 95–125 kHz.

In practice, these requirements mean that only small energy levels may be applied across the mains wiring. This in turn means that the receiver must be fairly sensitive and that spurious signals and the 50 Hz mains hum must be suppressed adequately. Moreover, as extra precautions, switching instructions must be sent several times, while at the receiver, received codes are compared several times

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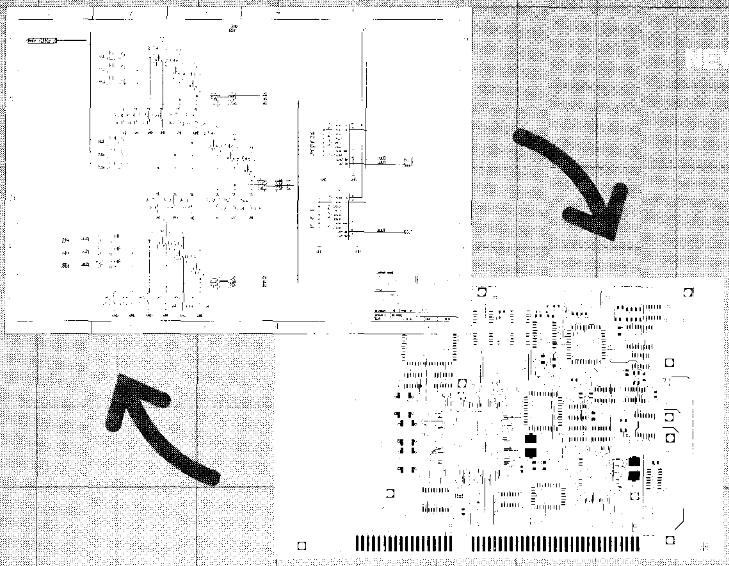

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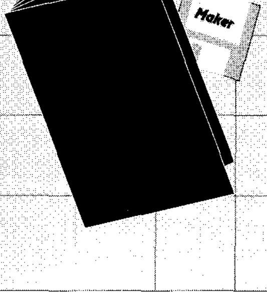

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FIGURING IT OUT

PART 15 – SINE WAVES AND OTHERS

By Owen Bishop

This series is intended to help you with the quantitative aspects of electronic design: predicting currents, voltage, waveforms, and other aspects of the behaviour of circuits. Our aim is to provide more than just a collection of rule-of-thumb formulas. We will explain the underlying electronic theory and, whenever appropriate, render some insights into the mathematics involved.

In all the discussions in this series up to the present, the only periodic inputs that we have considered have been sinusoidal waves. We now have to consider circuit behaviour when the input is periodic but is not sinusoidal. For example, in what way does a given circuit respond to a square wave, a rectified sine wave, or a sawtooth wave?

The situation seems fraught with complications because there are so many possible forms that waves may have. Fortunately, we are rescued by the work of Baron Jean Baptiste Joseph de Fourier (1768–1830) whose Fourier Series provides a way of expressing complicated but periodic functions in terms of sines and cosines. When a waveform has been analysed into a number of sine and cosine waves of different amplitudes, we calculate the behaviour of the circuit for each component, considered separately. Then we m ake use of the principle of superposition (Part 3) to find the response of the circuit to the complete waveform. The equation for the Fourier Series is described in detail later, but we look at some simple examples first.

Summing sines

The waveform of **Fig. 122** is clearly not sinusoidal, but it is easy to see that it is the sum of two sine wave of different amplitude, one having a frequency twice that of the other. These two components are shown separately in **Fig. 123**. In musical terms, the one with the lower frequency is termed the **fundamental**,. and the one with souble the frequency is the **first harmonic**. Between $t = 0$ and $t = \pi/2$, the waves reinformce each other, so that the resultant **Fig. 122**) peaks in that region. Between $t = \pi/2$ and $t = 3\pi/2$, the waves partly cancel out, causing the resultant to be flattened toward the x-axis. From $t = 3\pi/2$ to $t = 2\pi$, the waves reinforce again. We could add a constant term to the equation for **Fig. 122**, for example:

$$y = 6 + 4\sin t + 2\sin 2t \qquad \text{[Eq. 120]}$$

The effect of this is simply to shift the curve up the page. In electronic terms, the periodic signal is superimposed on a constant direct voltage, assuming that y refers to a voltage. In the discussions which follow, this variable might equally well represent a current or any other quantity which varies periodically.

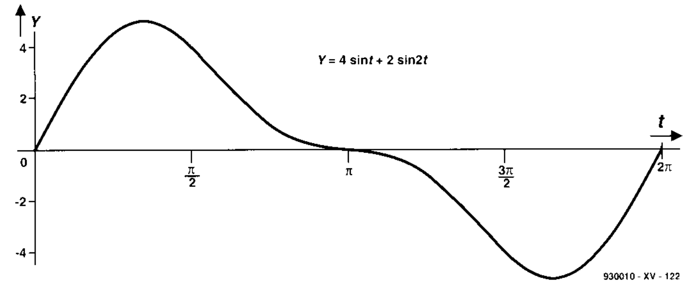

Fig. 122

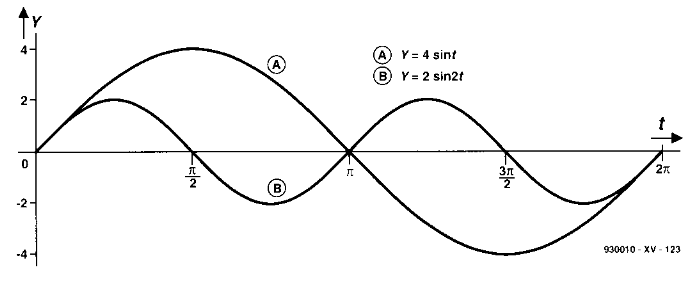

Fig. 123

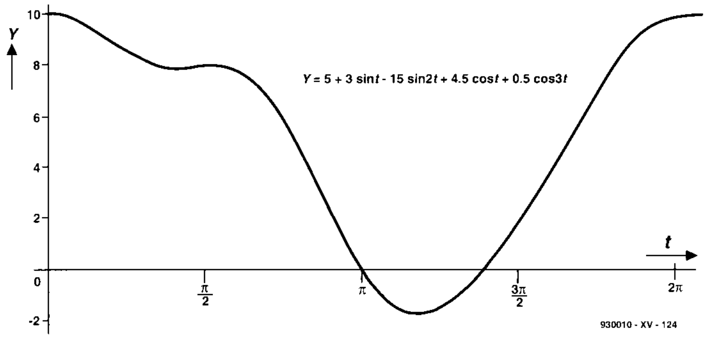

Fig. 124

Figure 124 shows a signal that has five components:

$$y = 5 + 3\sin t - 1.5\sin 2t + 4.5\cos t + 0.5\cos 3t \qquad \text{[Eq. 121]}$$

This might be taken to be the trace of an audio signal from a musical instrument as seen on the screen of an oscilloscope. As we shall later, although a Fourier Series has (in theory) an infinite number of terms, quite often only the first few terms need to be evaluated in practice.

So far, we have **synthesized** waveforms by writing out a series comprising a constant and one or more sine or cosine terms. Now we have to find out how to work in the opposite direction. Given a waveform such as the triangular wave of **Fig. 125**, we **analyse** it in to its components. But, before we leave the simple examples above, note these features of the series:

- a constant (d.c.) term;
- terms in $\sin t$, $\sin 2t$ (in general, $\sin nt$, where n is an integer);
- terms in $\cos t$, $\cos 2t \ldots \cos nt$;
- the terms have different coefficients, which may be positive or negative;
- the fundamental frequency is such that one cycle takes 2π seconds (we will explain how to deal with other fundamental frequencies later);
- all frequencies are multiples of the fundamental.

In practice, the series may be simplified if, for example, the constant term is zero, or the coefficients of all the sine terms or all the cosine terms are zero. Equation 120 is an example of a series in which the cosine terms all have a zero coefficient.

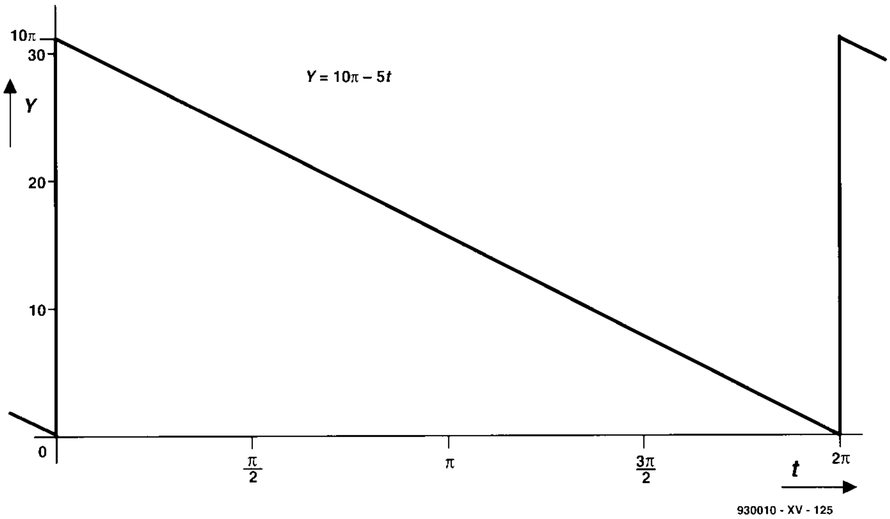

Fig. 125

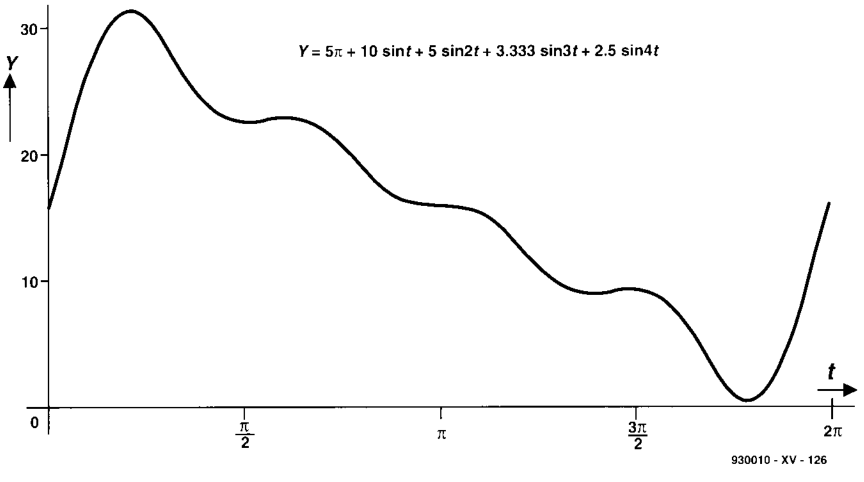

Fig. 126

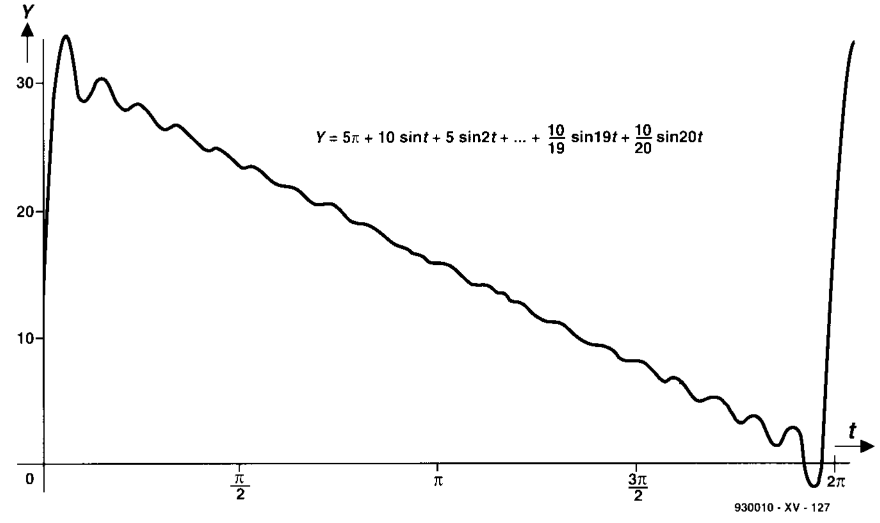

Fig. 127

Fourier series

The Fourier Series has this form:

$$y = A_0 + a_1\cos t + a_2\cos 2t + a_3\cos 3t + \ldots + a_n\cos nt + b_1\sin t + b_2\sin 2t + b_3\sin 3t + \ldots\ b_n\sin nt. \qquad \text{[Eq. 122]}$$

Although the equation is long and unwieldy, it breaks down into distinct parts as listed above. The constant term is A_0. We represent the coefficients of the cosine terms by $a_1, a_2, \ldots, a_n$, and the coefficients of the sine terms by $b_1, b_2, \ldots, b_n$. The important property of the Fourier Series is that, with some exceptions, any kind of periodic signal can be analysed as an equation of this form. Different signal have different sets of coefficients and our next task is to calculate these.

The first term is the mean values of y over 1 cycle. This fits in with the idea of the first term being equivalent to the steady direct voltage on which the signal voltage is superimposed. In the case of **Fig. 125**, it is easy to evaluate the first term simply by looking at the graph. During 1 cycle, y ramps down linearly from 10π to zero. The first term is the mean of 10π and zero. In grneral:

$$A_0 = 5\pi$$

$$A_0 = \frac{1}{2\pi}\int_0^{2\pi} y\,\mathrm{d}t \qquad \text{[Eq.123]}$$

This integral gives the area under the graph for a period of 1 cycle. The integral divided by the period (2π) is the mean value of y. In some cases, it may be easier

Integrating by parts

This technique is used to integrate the product of two expressions, both of which are functions of the same variable. We shall call the two parts u and $\mathrm{d}v/\mathrm{d}t$ (these symbols do not necessarily have anything to do with voltages).

In the example in the text, for finding cosine terms:

$u = y = 10\pi{-}5t$
$\mathrm{d}v/\mathrm{d}t = \cos nt.$

First, differentiate u:

$\mathrm{d}u/\mathrm{d}t = -5.$

Next, integrate $\mathrm{d}v/\mathrm{d}t$ to obtain v:

$v = (\sin nt)/n.$

The constant of integration is not required. The integral of the product is given by the formula

$$\int u\cdot \mathrm{d}v/\mathrm{d}t\,\mathrm{d}t = uv - \int v\cdot \mathrm{d}u/\mathrm{d}t\ \mathrm{d}t$$

Substitute u, v and $\mathrm{d}u/\mathrm{d}t$, and evaluate.

Applying this formula to the example:

$$a_n = \frac{1}{\pi}\int_0^{2\pi}(10\pi - 5t)\cos nt\,\mathrm{d}t$$

$$= \frac{1}{\pi}\{[(10\pi - 5)(\sin nt)/n]_0^{2\pi} - \int_0^{2\pi} -5(\sin nt)/n\,\mathrm{d}t\}$$

The integration is continued in the text.

Box 1

to integrate from $-\pi$ to $+\pi$. It does not really matter where in the cycle we begin, as long as we finish 2π seconds later.

Cosine terms

The formula for the coefficients of the cosine term is:

$$a_n = \frac{1}{\pi}\int_0^{2\pi} y \cos nt \, dt \qquad \text{[Eq. 124]}$$

This is similar to Eq. 123, but here we have a **product** to integrate. The product is $y \times \cos nt$ and, since y is a function of t, we must integrate **by parts** (see Box 1). Using this technique, we find that:

$$a_n = \frac{1}{\pi n}\{[(10\pi - 5t)\sin nt]_0^{2\pi} + 5\int_0^{2\pi} \sin nt \, dt\}$$

The second term on the right equals zero (see Box 2), leaving:

$$a_n = \frac{1}{\pi n}\{(10\pi - 10\pi)\sin 2n\pi + (10\pi - 0)\sin 0\}$$

$$= \frac{1}{\pi n}\{0 + 10\pi \sin 0\}$$

But, $\sin 0 = 0$, so

$$a_n = 0.$$

As a result of this, there are no cosine terms in the series. This considerably simplifies matters.

Useful integrals

Calculations are often made very much shorter when these integrals occur in an expression to be evaluated. Integration is with respect to t, over the limits 0 to 2π or $-\pi$ to $+\pi$, and n and m are positive integers.

Term to be integrated		Integral	Condition
$\sin nt$		0	
$\cos nt$		0	
$\sin^2 nt$		π	$n \neq 0$
$\cos^2 nt$		π	$n \neq 0$
$\sin nt \cos mt$		0	
$\cos nt \cos mt$		0	$n \neq m$
	or	π	$n = m$
$\sin nt \sin mt$		0	$n \neq m$
	or	π	$n = m$

Example: $\int_0^{2\pi} \sin 3t \cos 4t \, dt = 0$

Box 2

Sine terms

The formula for the coefficients of the sine terms is:

$$b_n = \frac{1}{\pi}\int_0^{2\pi} y \sin nt \, dt \qquad \text{[Eq.125]}$$

Integrating by parts:

$$b_n = \frac{1}{\pi n}\{[-(10\pi - t)\cos nt]_0^{2\pi} + 5\int_0^{2\pi} -\cos nt \, dt\}$$

The second term on the right equals zero (see Box 2), leaving:

$$b_n = \frac{-1}{\pi n}\{[-(10\pi - t)\cos nt]_0^{2\pi} + 5\int_0^{2\pi} -\cos nt \, dt\}$$

But $\cos 0 = 1$, so

$$b_n = 10\pi/\pi n = 10/n.$$

Thus, the sine terms have the form:

$$(10/n)\sin nt$$

for $n = 1, 2, 3, \ldots$

How many terms?

We are now in a position to assemble the series from the initial term and the coefficients. In Eq. 126, we take the series as far as the third harmonic:

$$y = 5\pi + 10\sin t + 5\sin 2t + 3.333\sin 3t + 2.5\sin 4t \qquad \text{[Eq. 125]}$$

This function is graphed for 1 cycle in **Fig. 126**. It shows undulating sine-like features, but is recognisably the triangular wave of **Fig. 125**. For such an un-sinusoidal waveform as a sharp-toothed triangular wave, we need more terms in the series to obtain a good representation. We extend the series until we obtain a waveform which we consider to be sufficiently close to the required waveform:

$$\ldots + 2\sin 5t + 1.667\sin 6t + 1.429\sin 7t + \ldots + 0.5\sin 20t.$$

Figure 127 shows the result of extending the series up to $n = 20$, the 19th harmonic. It is clear that, as we take more and more terms, the resulting function mapproaches more and more closely to that of the original triangular wave. It is only where there is a dramatic change that appreciable oscillations are observed.

Calculating and summing the terms is fast on a programmable calculator. However, the program memory may not cope with as many as 20 terms. A computer program in BASIC (**Fig. 128**) is easier to type and sums hundreds of terms, if required.

Circuit modelling

As an illustration of how the Fourier Series may be used in modelling, we will see what happens to the sawtoothed voltage wave of **Fig. 125** when it is applied to the circuit of **Fig. 129**, which is a passive high-pass filter. Remember that the period of the wave is 2π. Its frequency is $1/2\pi = 0.159$ Hz. To have any effect on the lower harmonics, we need a capacitor of relatively high value. With the values shown in **Fig. 129**, the -3 dB point is 2 Hz.

We now need to examine the terms of the Fourier Series for y and find what happens to them when fed into the filter. The first term, 5π, is a d.c. term and does not pass through. Recalling the technique used in Part 6 to calculate the attenuation and phase

```
10 FOR t = 0 TO 6.4 STEP 0.05
20 u = PI*5
30 FOR n = 1 TO 20
40 u = u + 10/n*SIN(n*t)
50 NEXT
60 PRINT £8, t;"    ";ROUND(u,3)
70 NEXT
```

930010 - XV - 128

Fig. 128

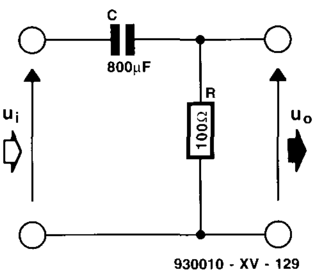

Fig. 129

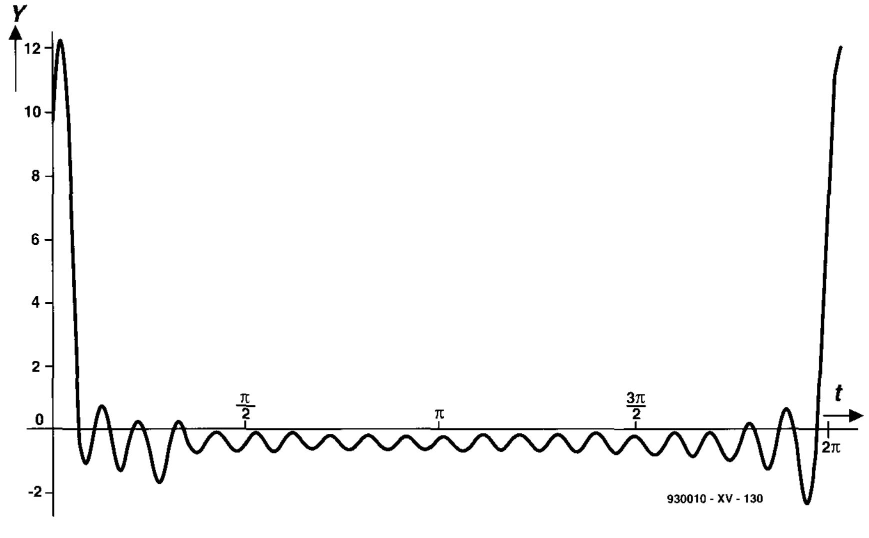

Fig. 130

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lag of a low-pass filter (**Fig. 52**), we calculate the effect of the high-pass filter of **Fig. 128** on the fundamental component, $y = 10\sin t$. The total impedance of the filter is:

$$Z = R - \mathbf{j}/\omega C,$$

where we express the impedance of the capacitor as a complex number (see Part 9). Given that $\omega = 1, R = 100$ and $C = 800\times10^{-6}$,

$$Z = 100 - \mathbf{j}1250,$$

or, in polar form:

$$Z = 1254\ \angle{-1.49}.$$

Angles are in radians. Considering the filter as a potential divider, its output is u_R, and:

$$u_{out} = u_{in}\cdot 100/Z.$$

For the fundamental, the peak values of u_{in} is 10 V (the coefficient of the $\sin t$ term of the series).

$$u_{out} = 1000/(1254\ \angle{-1.49}) = 0.7974\ \angle 1.49.$$

The output signal is attenuated to about 0.8 V peak and **leads** the input by 1.49 rad.

We can similarly find u_{out} for each of the harmonics, expressed in polar form. The values of R and C remain the same, but ω becomes 2, 3, 4, ... for successive harmonics. The outputs are attenuated by different amounts and have different phase leads. These outputs can not be added in the usual way, as phasors, because they are all of different frequencies. We therefore express each of them as a sine wave of given amplitude and period with a given phase lead. In this form, the output from the fundamental is:

$$u_{out} = 0.7974\sin(t + 1.49).$$

Summing the outputs for the fundamental and the first 19 harmonics, we have:

$$\begin{aligned} u_{out} = {} & 0.7974\sin(t + 1.49) \\ & +0.7900\sin(2t + 1.41) \\ & +0.7778\sin(3t + 1.34) \\ & +\ldots\ 0.5771\sin(12t + 0.81) \\ & +\ldots\ 0.4241\sin(20t + 0.56). \end{aligned}$$

Note that the coefficients decrease, but much more slowly than in the original function. This reflects the fact that the higher frequencies are less attenuated than the lower frequencies. Also, the phase lead is leass as frequency increases. When $\omega = 12$, $f = \omega/2\pi = 1.91$, which is approximately at the –3 dB point of the filter. The input amplitude of this component is $10/12 = 0.8333$ and its output amplitude is 0.5771. The attenuation is $0.5771/0.8333 = 0.69$. This is roughly 0.7, the expected attenuation at the –3 dB level. The phase lead is 0.81 rad., equivalent to 46°, close to the lead of 45° expected at the –3 dB point.

A graph of u_{out} appears in **Fig. 129**. It shows that filtering has a dramatic effect on the sawtooth wave, reducing it to a series of spikes, where the voltage suddenly steps up at the beginning of each cycle. The circuit filters out the slow change of voltage as waveform ramps down. This graph has more pronounced undulations than **Fig. 127**; this is due to the fact that the high-pass filter makes the higher frequencies relatively prominent.

In the example above we have illustrated the use of the Fourier Series by modelling a simple waveform being passed through a circuit with a simple response. There are easier ways of doing this, as we shall see in Part 17. It is with more elaborate waveforms and more complicated circuits that the Fourier Series shows its power. With a computer to provide help with the calculations, this is a useful technique for analysing circuit behaviour. Next month, we show how to tackle other types of wave and we look at ways of shortening the calculations.

Test yourself

A triangular waveform ramps up according to the equation $y = 2t$, repeating every 2π .seconds. Express this as a Fourier Series, as far as the 3rd harmonic. This signal is applied to a low-pass filter having the same components as **Fig. 129**, but with R and C interchanged. Calculate a series for the waveform of the output signal as far as the 3rd harmonic.

Answers to Test yourself (Part 14)

1. $i = 0.3(e^{-t} - e^{-2t}) + 0.06923e^{-2t} - (9\cos 3t + 7\sin 3t)/130.$

2. $i = 0.03316e^{-4t} - 0.02036e^{-246t} - 0.0128e^{-0.4545t}$. Current $= 774\ \mu A$.

3. $d^2i/dt^2 + 10000\,di/dt + 5000i = 4e^{0.5t}$.
   $i = Ae^{-5t} + Be^{-9995t} + (7.27\times10^{-5})\,e^{0.5t}$.
   $i = 0.0003277(e^{-5t} - e^{-9995t}) + (7.27\times10^{-5})(e^{0.5t} - e^{9995t})$.
   Current = 0.275 mA.

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BD535	£0.48
BD536	£0.65
BD646	£0.52
BD648	£0.52
BD650	£0.53
BD707	£0.42
BD807	£0.80
BDX32	£1.78
BDX33C	£0.46
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.31
BF194	£0.19
BF195	£0.19
BF244	£0.35
BF257	£0.33
BF259	£0.33
BF337	£0.36
BF355	£0.38
BF423	£0.13
BF451	£0.19
BF459	£0.29
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.31
BFY50	£0.29
BFY51	£0.26
BFY52	£0.28
BS107	£0.21
BS170	£0.21
BSW66	£1.35
BU126	£1.70
BU205	£1.82
BU208A	£1.73
BU326A	£1.80
BU500	£2.32
BU508A	£1.76
BU526	£2.24
BU806	£1.36
BUX84	£0.78
IRF540	£1.60
IRF740	£1.63
MJ11015	£2.11
MJ11016	£2.11
MJ2501	£1.60
MJ3001	£1.52
MJE340	£0.40
MJE350	£0.42
MPSA13	£0.12
MPSA42	£0.17
MRF475	£6.21
TIP121	£0.35
TIP122	£0.37
TIP125	£0.37
TIP127	£0.37
TIP132	£0.46
TIP137	£0.46
TIP142	£1.08
TIP147	£1.12
TIP2955	£0.63
TIP29C	£0.31
TIP3055	£0.63
TIP30C	£0.31
TIP31C	£0.34
TIP32C	£0.32
TIP33C	£0.72
TIP41A	£0.36
TIP42C	£0.38
TIP47	£0.48
TIP48	£0.62
TIP50	£0.53
VN10KM	£0.44
VN66AF	£1.50
ZTX300	£0.16
ZTX500	£0.16

TRIACS

Type	Price
Z0105DA	£0.42
TIC206D	£0.65
TIC226D	£0.73
BTA08-600B	£0.84
TIC236D	£0.96
DIAC	£0.20

VOLTAGE REGULATORS

Type	Price
78L05	£0.24
78L12	£0.24
78L15	£0.24
79L05	£0.28
79L12	£0.28
79L15	£0.28
7805	£0.28
7812	£0.28
7815	£0.28
7905	£0.38
7912	£0.38
7915	£0.38
LM317T	£0.56
LM723	£0.29
L200CV	£1.16
LM323K	£2.70
LM338K	£5.52

THYRISTORS

Type	Price
PO102AA	£0.30
TIC106D	£0.40
TIC116D	£0.66
TIC126D	£0.77

HARDWARE

Item	Price
T2 Box 75 x 56 x 25mm	£0.82
T3 Box 75 x 51 x 25mm	£0.82
T4 Box 111 x 57 x 22mm	£0.98
MB1 Box 79 x 61 x 40mm	£1.44
MB2 Box 100 x 76 x 41mm	£1.56
MB3 Box 118 x 98 x 45mm	£1.82
MB5 Box 150 x 100 x 60mm	£2.50

ELECTROLYTIC RADIAL CAPACITORS

uF	16V	25V	63V	100V	450V
0.47			£0.05	£0.07	-
1.0	-	-	£0.05	£0.06	£0.15
2.2	-	-	£0.05	£0.06	£0.18
4.7	-	-	£0.05	£0.08	£0.30
10	£0.05	£0.05	£0.06	£0.08	£0.48
22	£0.05	£0.05	£0.09	-	-
47	£0.06	£0.06	£0.11	-	-
100	£0.06	£0.09	£0.11	-	-
220	£0.09	£0.12	£0.31	-	-
470	£0.15	£0.19	£0.57	-	-
1000	£0.22	£0.29	-	-	-
2200	£0.37	£0.57	-	-	-
4700	-	£1.11	-	-	-

ELECTROLYTIC AXIAL CAPACITORS

uF	16V	25V	63V	100V	450V
0.47	-			£0.15	
1.0	-	-	£0.10	£0.10	£0.19
2.2	-	-	£0.10	£0.10	£0.22
4.7	-	£0.09	£0.10	£0.10	£0.34
10	-	£0.12	£0.12	£0.12	£0.48
22	-	£0.09	£0.13	£0.17	£1.06
47	£0.10	£0.11	£0.16	£0.20	£1.33
100	£0.10	£0.13	£0.21	-	£2.46
220	£0.13	£0.18	£0.42	-	-
470	£0.21	£0.24	£0.69	-	-
1000	£0.33	£0.40	£1.05	-	-
2200	£0.52	£0.64	-	-	-
4700	£0.90	-	-	-	-

LINEAR ICs

Type	Price
CA311E	£0.28
CA324	£0.35
CA555	£0.22
CA741CE	£0.25
CA747CE	£0.39
CA3046	£0.37
CA3080	£0.72
CA3130	£0.98
CA3130E	£0.98
CA3140	£0.56
CA3240	£1.22
ICL7621	£1.70
ICM7555	£0.43
ICM7556	£0.96
LM301A	£0.25
LM348N	£0.31
LF351N	£0.36
LF353	£0.41
LM358N	£0.27
LM377	£2.57
LM380N	£1.12
LM381	£2.70
LM386	£0.48
LM387	£1.60
LM392N	£0.79
LM393N	£0.28
LM748CN	£0.31
LM1458	£0.26
LM3900	£0.72
LM3914	£2.70
LM3915	£2.70
MC3340	£1.60
MC4558	£0.36
NE531	£1.56
NE556N	£0.36
NE567N	£0.36
NE5532	£0.80
NE5534	£0.66
TBA120S	£0.77
TBA810S	£0.68
TBA820M	£0.39
TDA2030	£1.35
TL061	£0.35
TL062	£0.42
TL064	£0.46
TL071CP	£0.32
TL072CP	£0.34
TL074CN	£0.48
TL081	£0.33
TL082CP	£0.34
TL084CN	£0.46
UA733	£0.64
ULN 2003	£0.52
ULN2004	£0.48
ZN414Z	£1.04
ZN425E	£4.68
ZN426E	£2.61
ZN427E	£8.82
ZN428E	£6.12
ZN435E	£5.31
ZN448E	£7.92

EPROMS & RAMS

Type	Price
2716	£4.46
2732	£4.84
2764 25	£3.00
27C64-25	£2.80
21728-20	£3.69
27C128-20	£3.31
27256-20	£3.99
27C256 20	£3.57
27C512	£3.69
27C010	£4.97
6116-10	£1.53
6264 10	£3.06
62256-10	£4.83
4164-15	£1.78
41256 10	£2.80
511000-8	£5.61
514256-8	£5.61

DIL SOCKETS

Type	Price
8 Pin	£0.07
14 Pin	£0.11
16 Pin	£0.15
18 Pin	£0.15
20 Pin	£0.16
24 Pin	£0.19
28 Pin	£0.22
40 Pin	£0.25

SOLDERING IRONS

Item	Price
Antex Soldering irons	
M 12 Watt	£7.75
C 15Watt	£7.78
G 18Watt	£7.96
CS 17Watt	£7.88
XS 25Watt	£7.96
ST4 STAND	£2.85
35Watt Gas Iron	£11.58
Desolder Pump	£3.00
Antistatic Pump	£4.30
22SWG 0.5Kg Solder	£7.40
18SWG 0.5Kg Solder	£6.60
1mm 3 yds Solder	£0.62
Desolder Braid	£0.87

RF CONNECTORS

Item	Price
BNC Solder Plug 50R	£0.93
BNC Solder Plug 75R	£0.96
BNC Crimp Plug 50R	£0.68
BNC Crimp Plug 75R	£0.68
BNC Solder Skt	£1.08
BNC Chassis Skt	£0.80
PL259 5.2mm	£0.68
PL259 11mm	£0.62
RND UHF socket	£0.68
SQR UHF socket	£0.45
F Plug RG58	£0.30
F Plug RG6	£0.27
N Plug RG8	£1.60
N Socket RG8	£1.40
BNC Crimp Pliers	£15.50

PCB EQUIPMENT

Item	Price
UV EXPOSURE UNIT	£67.38
PLASTIC DEVELOPING TRAY	£1.35
PHOTO RESIST AEROSOL SPRAY (100ml)	£3.90
FERRIC CHLORIDE CRYSTALS (0.5Kg)	£2.45
TIN PLATING POWDER (90g)	£10.80
ETCH RESIST PEN	£0.72
PCB POLISHING BLOCK	£1.84

STRIPBOARD 0·1 PITCH

Size	Price
64mm x 25mm	£0.27
64mm x 95mm	£0.90
64mm x 431mm	£3.22
95mm x 127mm	£1.50
95mm x 95mm	£1.10
95mm x 431mm	£4.80
100mm x 160mm	£1.60
119mm x 454mm	£6.20

BREADBOARD

Size	Price
81mm x 60mm	£3.06
175mm x 42mm	£3.74
175mm x 67mm	£5.56
203mm x 75mm includes mounting plate & posts	£7.36

COPPER BOARD (G. Fibre)

Size	Price
100mm x 160mm	£0.90
110mm x 220mm	£1.24

PHOTO RESIST BOARD (G. Fibre)

Size	Price
3" x 4"	£0.86
4" x 6"	£1.62
4" x 8"	£2.09
6" x 6"	£2.41

PHOTO RESIST BOARD (Paper)

Size	Price
3" x 4"	£0.67
4" x 6"	£1.24
4" x 8"	£1.58
8" x 10"	£4.63

CAPACITORS

Ceramic Mini Disc 100 & 63V
1.0pF to 100nF
1pF-1nF **£0.06**, 1n2 2n7 **£0.07**,
3n3 4n7 **£ 0.12**,
10n & 12n **£0.07**
Polystyrene 160V 5% 47pF to 10nF
47p-2n2 **£0.09**, 2n7 10n **£0.12**

D CONNECTORS

	Plug	Socket
9 Pin	£0.29	£0.30
15 Pin	£0.39	£0.39
15 Pin H.D.	£0.81	£0.90
23 Pin	£0.40	£0.49
25 Pin	£0.48	£0.50
9 Way plastic cover		£0.30
15 Way plastic cover		£0.33
23 Way plastic cover		£0.36
25 Way plastic cover		£0.36

BRIDGE RECTIFIERS

Type	Price
W005 1.5A 50V	£0.19
WO2 1.5A 200V	£0.20
BR32 3A 200V	£0.36
BR62 6A 200V	£0.64
1004 10A 400V	£1.39

SWITCHES

Item	Price
3amp 250v 6.4mm ⌀ mounting	
SPST Toggle	£0.58
SPDT Toggle	£0.60
SPDT CO Tog	£0.64
DPDT Toggle	£0.68
DPDT CO Toggle	£0.76
DPDT CO Toggle (biased)	£1.20
DPDT CO Toggle (biased 1 way)	£1.20
DPDT mini slide	£0.15
Rotary Wafer 1P 12W, 2P-6W, 3P 4W, 4P-3W	£0.78
Key Switch SPST	£2.70
Push to make	£0.25
Push to break	£0.28
Latching Push Sqr	£0.63
PCB Tact 6 x 6mm	£0.25

RESISTORS

Item	Price
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0.5W 5% CF E12 Series	**£0.95**/100
0.25W 1% MF E24 Series	**£1.72**/100
POTS Log or Lin 470R 1MO 25mm dia 0.25in shaft	£0.42
PRESETS Enclosed Horz or Vert 100R 1MO 0.15W	£0.15
PRESETS Skeleton Horz or Vert 100R 1MO 0.1W	£0.11

★ PLEASE STATE VALUE REQUIRED ★

COMPUTER ACCESSORIES

Item		Price
Parallel Printer Lead 2m		£6.90
RS232 Lead (all pins) Male Male		£3.75
RS232 Lead (all pins) Female Male		£3.80
Centronics 36 Way Lead Male Male		£4.78
Gender Changers		
9 Way D Mini Female to Female		£1.81
9 Way D Mini Male to Male		£1.98
25 Way D Mini Female to Female		£2.23
25 Way D Mini Male to Male		£2.23
9 Way D Female to Female		£2.33
9 Way D Male to Male		£2.33
25 Way D Female to Female		£2.71
25 Way D Male to Male		£2.71
Adaptors		
9 Way Male to 25 Way Female		£2.71
9Way Female to 25Way Male		£2.71
25 Way Male to 9 Way Female		£2.33
25 Way D Male to 36 Way Centronic		£3.56
25 Way Null Modem Female Female		£3.02
25 Way Null Modem Male to Female		£3.02
25 Way Null Modem Male to Male		£3.02
RS232 Surge Protector Male - Female		£6.12
RS232 Jumper Box Male to Female		£3.02
RS232 Tester (7 LEDs) Male Female		£6.59
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Serial Switch box	2 Way A/B	£9.20
Serial Switch box	3 Way A/B/C	£13.16
Serial Switch box	4 Way A/B/C/D	£15.15
Serial Switch box	Cross over	£19.69
Parallel box	2 Way A/B	£11.84
Parallel box	3 Way A/B/C	£17.11
Parallel box	4 Way A/B/C/D	£18.43
Parallel box	Cross over	£20.42

DIODES

Type	Price
Zener Diodes 2V7 33V	
BZY88400Mw	£0.08
BZX85 1.3W	£0.14
1N4001	£0.06
1N4002	£0.07
1N4003	£0.07
1N4004	£0.07
1N4005	£0.07
1N4006	£0.08
1N4007	£0.08
1N5400	£0.09
1N5401	£0.09
1N5402	£0.09
1N5404	£0.11
1N5406	£0.11
1N5407	£0.14
1N5408	£0.15
1N914	£0.06
1N916	£0.06
1N4148	£0.05
BY133	£0.13
OA47	£0.28
OA90	£0.07
OA91	£0.10
OA202	£0.27
BA157	£0.10
BA158	£0.10
BA159	£0.10
1N4149	£0.06
OA200	£0.10

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DIRECT CONVERSION RECEIVERS

PART 2 (final)

SOME NOTES ON DESIGN AND CONSTRUCTION TECHNIQUES, AND THREE PRACTICAL EXAMPLES

By Joseph J. Carr, B.Sc., MSEE

In the previous instalment of this article we examined the theory behind direct conversion receivers (DCR). In this final instalment we will take a look at three simple projects that are based on the principles discussed in Part 1. Three different designs are selected for testing: the 40 and 75/80-meter bands 'Neophyte' design by John Dillon[1]; a 40-meter band HF receiver based on the passive DBM designs of Lewallen and Campbell[2]; and a VLF design. All three designs were fabricated and tested on a common test chassis built especially for the purpose.

The common test chassis

Part of the decision to build and test several direct conversion receivers involved having a common chassis for all three designs. Although not very elegant, being made of scrap aluminum chassis and bottom plates from the 'junk box', it was at least low cost and effective. **Figure 1** shows the receiver test bed front panel. It is fitted with a Jackson Brothers calibrated dial with a 10:1 fast/slow vernier drive. The 6.35-mm (0.25-in.) shaft coupling on the vernier drive is used to turn either a variable air dielectric capacitor or potentiometer, depending on whether the DCR being built is a mechanically tuned or voltage tuned version. For most of the experiments the voltage tuned variety was used. Two additional controls are also provided, and both are potentiometers. The pot to the right of the tuning knob is a volume control, while that to the left is the RF tuning control (for voltage tuned front-end circuits).

Three circuits are provided for the test bed: two d.c. power supplies and an LM386 audio power amplifier. One d.c. power supply (**Fig. 2**) is used to provide +12 V regulated to the circuits of the DCRs used on the test bed. It uses a 7812 three-terminal IC voltage regulator, and works from a 15 Vd.c., or higher source. In the case of this project, raw power was provided by two 9-V dry-cell batteries connected in series. The second d.c. power supply (**Fig. 3**) consists of a 78L12 low-power, three-terminal voltage regulator and a potentiometer. The potentiometer is for main tuning, and is ganged to the main dial of the chassis. In normal use, this potentiometer is used to tune the local oscillator (LO) of the DCR.

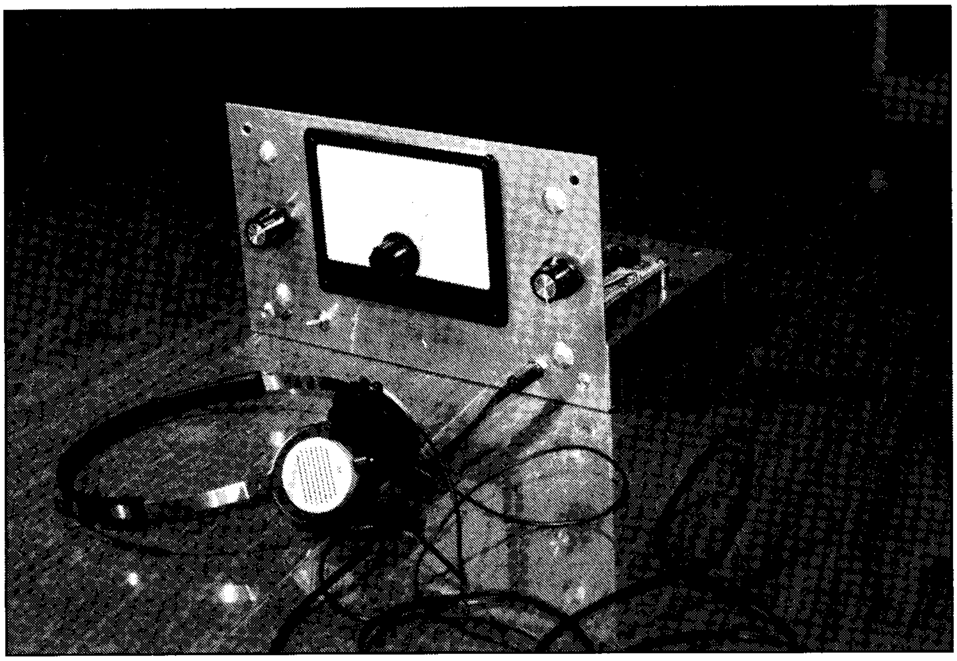


Fig. 1. Test chassis for direct conversion experiments. This chassis incorporates the DC power supplies, tuning voltages for RF and LO, and an LM386 audio amplifier stage.

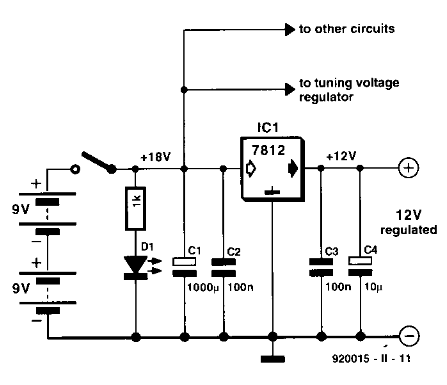


Fig. 2. DC power supply for the DCR test chassis. A pair of 9 volt batteries provides primary power, which is then regulated to 12 V by a 7812 IC voltage regulator.

The audio amplifier is the LM386 low-power 'audio system on a chip' device. The LM386 uses a minimum of external components, and includes both the audio preamplifiers and the power amplifiers to produce between 250 mW and 700 mW of audio power, depending on the particular device specified. The circuit for the audio section is shown in **Fig. 4**, while its location on the test bed chassis is shown in **Fig. 5**. Note that the audio section has its own +12-V regulator. This is an optional feature, but does serve to keep load variations in the audio amplifier from coupling to the rest of the circuitry. The audio section is the small circuit board on the left side of the chassis right by the audio volume control.

Figure 5 shows the rear view of the DCR test bed chassis. As mentioned, the audio amplifier section is shown on the left. The gray metal box contains either the variable air-dielectric capacitor, or potentiometer and power supply (**Fig. 3**),

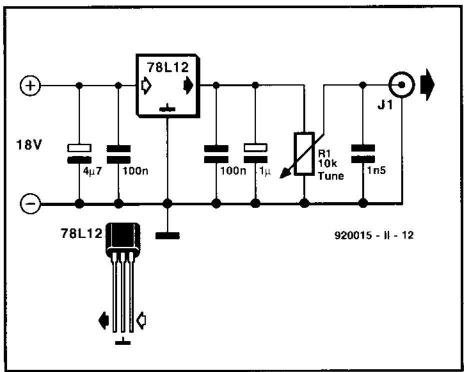


Fig. 3. Tuning voltage source. Potentiometer R1 is mechanically ganged to the main tuning dial and gear assembly.

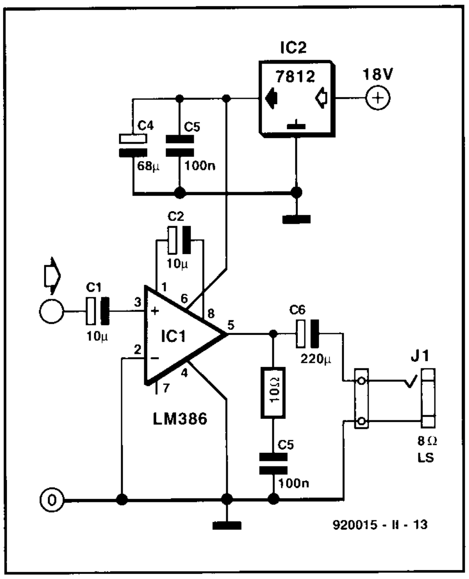


Fig. 4. Circuit for the LM386 audio amplifier stage on the DCR test chassis.

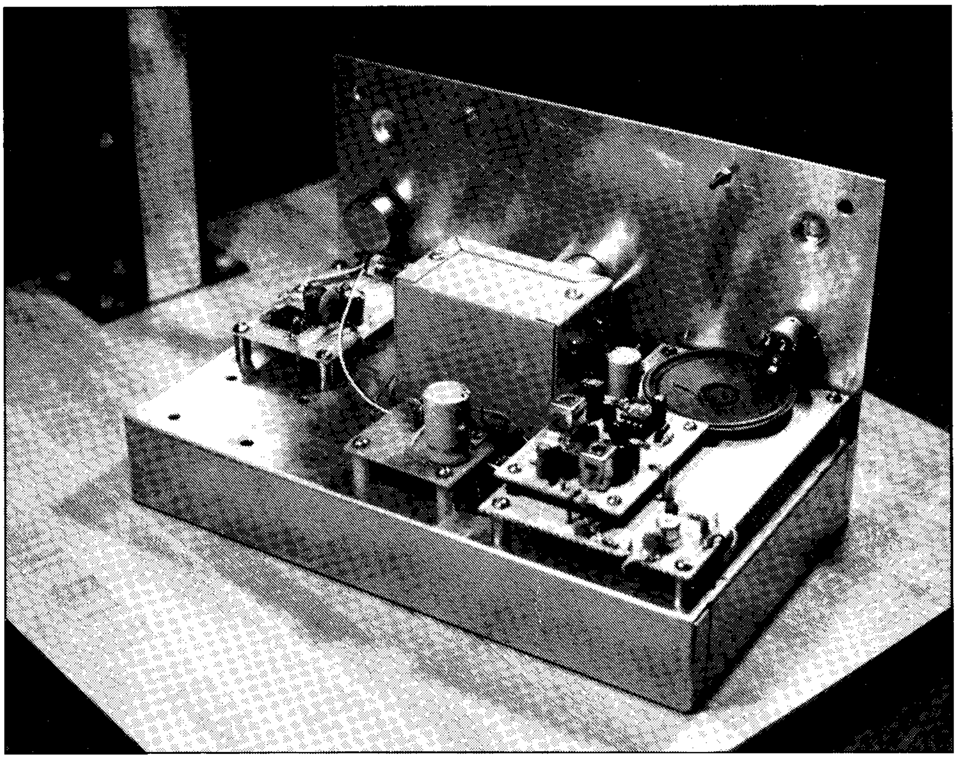


Fig. 5. Rear view of the DCR test chassis. Audio stage is on the left side, while the tuning voltage circuit is within the shielded metal enclosure. The main voltage regulator is behind the tuning voltage box (main batteries beneath chassis). Each test receiver was fabricated on a piece of perforated circuit board (shown here with the Dillon receiver mounted). In this example the audio stage was not needed because it was incorporated in the commercial printed circuit board mounted to the receiver board.

either of which may be used to tune the local oscillator of the DCRs being tested. The 12-V d.c. power supply is located on the small printed circuit board to the rear of the tuning box. Space is provided to the right of the tuning box for the circuitry of the DCR being tested. This board is changed from one project to the other.

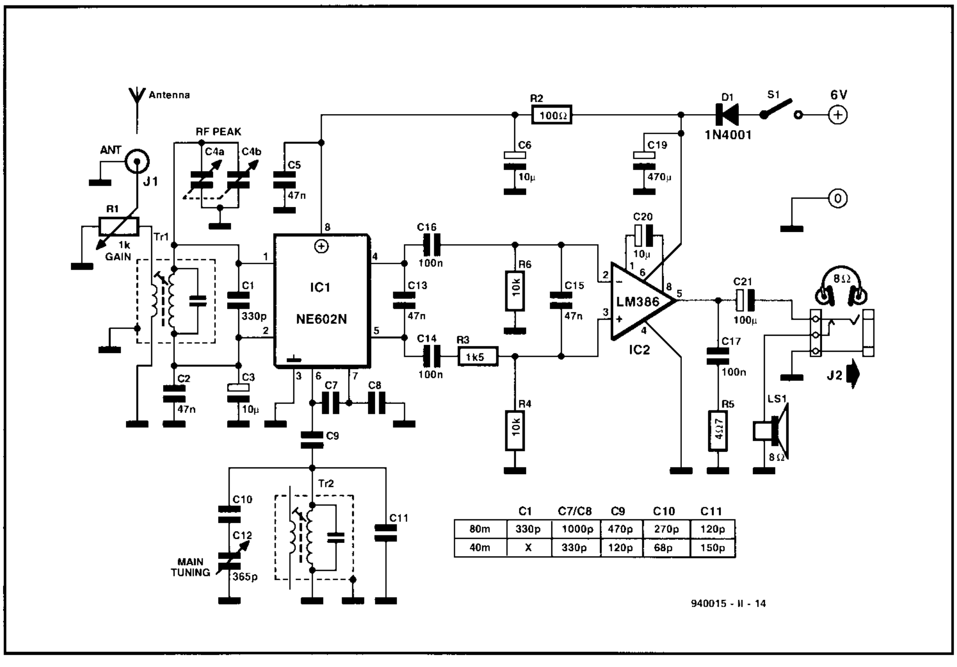
Wiring board construction used two different methods. The audio amplifier, the tuning d.c. power supply and 12-V d.c. regulated power supply were built on Radio Shack (Tandy) 'universal' printed circuit boards. The DCRs, on the other hand, were wired using Vector perfboard with a hole grid on 0.1-inch centres, or an equivalent product.

Three different antennas were used for testing the DCRs in this article: a 5BTV Cushcraft ½-wavelength ham band vertical, an outdoor 30-m (100-ft) random length end-fed wire, and a 6-m (20-ft) wire strung across the ceiling of my basement workshop. Interestingly enough, on the HF bands there was not a large difference between the outdoor antennas' performance and only slightly more difference between the outdoor antennas and the indoor antenna. On the VLF band, however, the random length wire was clearly superior to the other two antennas.

75/80 and 40-m NE602 design

The first DCR tested is the John Dillon design, which was originally published in *QST*[3] and discussed in Part 1 of this article. The Dillon design is based on the Signetics NE602 frequency converter chip available in the form of a parts kit from PennTek Electronics in the USA (14 Peace Drive, Lewistown, PA 17044, USA; Phone: 717-248-2507 — overseas callers note: normally a recording answers). The kit contains a printed circuit board and all of the electrical parts needed to build the receiver except for the variable capacitors. These capacitors are becoming difficult to obtain in the USA, but the Maplin (P.O. Box 777, Rayleigh, Essex, SS6 8LU, UK; phone 0702 554171) catalogue in UK offers several reasonable candidates for both RF and LO tuning capacitors.

The circuit for the Dillon design is shown in **Fig. 6**. The RF 'heart' of the circuit is the NE602 converter chip. The NE602 contains the local oscillator (LO) and a transistor double-balanced mixer (DBM) in the form of a transconductance cell. This design provides about 20 dB of conversion gain, good sensitivity, and rejection of the LO and RF signal components in the output. However, the early design chip is a little lacking in dynamic range (a problem reputedly corrected in the updated NE612 chip). The Dillon DCR



	C1	C7/C8	C9	C10	C11
80m	330p	1000p	470p	270p	120p
40m	X	330p	120p	68p	150p

Fig. 6. Circuit for the Dillon H.F. DCR.

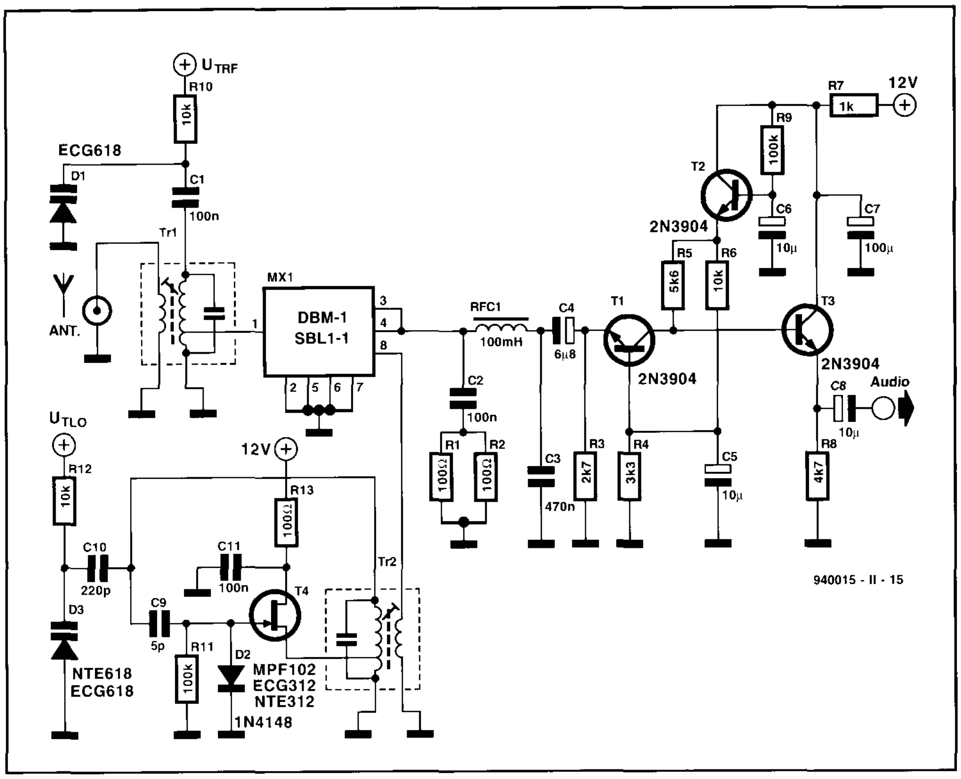


Fig. 7. DCR design based on a commercial passive double balanced mixer (DBM).

uses the balanced outputs of the NE602 (most designs are single-ended) in an effort to improve AM rejection. Likewise, to match the NE602 output scheme, the LM386 audio amplifier is wired in the differential input configuration.

Dillon's commercially produced printed circuit board was mounted on a piece of perf-board (see **Fig. 5** again) that was cut to fit the space available on the test bed chassis. In addition to the Dillon board, the perf-board contained the circuitry for the RF and LO varactor circuits and a 7806 three-terminal voltage regulator to reduce the 12 V available on the test bed to the 6 V specified by Dillon.

The Dillon receiver can be used on either 75/80 meters, or 40 meters, depending on how the oscillator is configured. The performance is optimized for 75/80 meters, according to Dillon. In a telephone conversation John Dillon told the author that the 40-meter band was added later in accordance with the wishes of the original publisher of the project. However, despite Dillon's reservations, I found the 40-meter performance to be about the same as the 75/80 meter performance with the possible exception of overload problems due to the high power AM signals from international broadcasters found in the 40-meter band.

The Dillon design proved to be remarkably sensitive, much more so than I anticipated. Perhaps that is an advantage of the 20-dB conversion gain of the NE602.

Criticisms of the design include two things related to the audio amplifier.

First, there is no volume control. The level of the output signal is controlled by a 1000-Ω linear taper potentiometer that varies antenna signal to the RF front-end. I found the lack of a volume control disconcerting, but not overwhelmingly so.

Second, there is a general criticism of this design and all other designs I built where the LM386 is used alone for the audio stage without preamplification. The audio gain is insufficient to provide for really comfortable listening, especially when a loudspeaker was used instead of earphones. I believe that this could be relieved by adding a preamplifier stage ahead of the LM386. If the differential nature of the circuit is to be preserved, then an operational amplifier can be used for this purpose. Several candidate op-amps (or operational transconductance amplifiers) are available that work well on single polarity d.c. power supplies.

A crude test of this theory proved interesting. I attenuated the output of Dillon's receiver with a 1000-Ω potentiometer to make it compatible with the input of the LM386 audio amplifier that is used in the DCR test bed. The total gain of the two LM386s, even with some attenuation, was considerably higher than the gain of the receiver circuit alone. The result was loud and clear signals that would not tax a middle-aged, hard of hearing guy like me. Dillon confirmed the lack of audio gain[5]. He told me that he had designed a three-IC version that inserted a dual op-amp between the NE602 and LM386 (one section was a preamplifier and the other an audio filter). He stated that the present design was selected because of a goal of two-IC simplicity.

My general assessment of the Dillon design is that it makes a decent weekend project for anyone who wishes to experiment with direct conversion radio receivers. The receiver can be used as designed, or easily modified if that is your preference. It is easy to modify for bands other than the amateur radio bands because both its circuitry and mechanical implementation are straight forward. It also provides a basis for experimenting with other variations of the basic design.

High-frequency DCR based on passive DBM

The next receiver that I built and tested was a high frequency design based on the MiniCircuits (P.O. Box 350166, Brooklyn, NY, 11235-0003, USA; phone 718-934-4500) SBL-1-1 passive double-balanced mixer (DBM). This mixer device provides frequency conversion up to 500 MHz, at LO power levels up to +7 dBm and RF levels up to +1 dBm. For higher dynamic range performance, there are variants that accept higher levels in both the LO and RF ports. The cost of those devices, however, is also higher than the SBL-1-1. If the SBL-1-1 is not easily available, then substitute the SRA-1 or SBL-1 designs. Alternatively, it is relatively easy to achieve reasonable performance using a homebrew passive DBM (see Part 1 of this series). Such circuits use toroidal coupling transformers and hot carrier RF diodes for mixing. The RF signal is applied to pin 1 of either SRA-1 or SBL-1 devices, while the LO is applied to pin no. 8; pins 2, 5, 7 and 8 are grounded. The IF output is found on pins 3 and 4, and these pins must be connected together for proper operation.

The circuit for this receiver is shown in **Fig. 7**. The circuit was built on a piece of perf-board cut to fit the space available on the test bed. The RF front-end of the receiver consists of a 10.7-MHz IF transformer intended for FM transistor radios; a Mouser Electronics (2401 Highway 287 N, Mansfield, TX, 76063, USA; phone 817-483-4422) type 42IF123 was used. FM IF transformers are a little broad banded (>200 KHz) for this application, but are convenient. A higher *Q*, narrower band transformer can be built if desired.

Another problem with the 10.7-MHz IF transformer is that the tap is not a good match to 50 Ω because the tap seems to be at a point where the impedance is apparently a couple of hundred ohms. However, the mismatch did not deteriorate the performance so much that it overcame the convenience of the easy-to-obtain transformer. Optimization of the circuit requires an RF transformer designed with a 50-Ω tap.

The internal capacitor of the IF transformer can be disconnected if desired, although I used it as part of the tuning capacitance for the circuit. At frequencies higher than 11 MHz, however, the capacitor will have to be removed. This capacitor is found in a small external recess in the base of the IF transformer. It is not easy to 'disconnect' the capacitor without a lot of work and potential damage to the transformer. The best way to get rid of the capacitor is to crush it with a small probe or screwdriver tip. Be sure to remove the debris to keep it from shorting other circuits.

The circuit as shown will tune from about 5 MHz to greater than 9 MHz when the 440-pF varactor is used. The total capacitance seen by the transformer secondary consists of the internal capacitor (unless removed) plus the combined capacitance of C_1 and D_1. This capacitance is:

$$C_{TRF} = (C_1 C_{D1}) / (C_1 + C_{D1}) \qquad [2]$$

You can change the range of the tuning by using other values of capacitance than the 10 nF shown. When the 10-nF capacitor is used, the total capacitance is very nearly the capacitance of the diode. Other implementations of C_1 can include combinations of smaller valued fixed and variable (trimmer) capacitors.

The local oscillator for the receiver is a JFET Hartley oscillator that uses the same type of IF transformer as the RF input circuitry for main tuning. The secondary of the transformer is tuned to 10.7 MHz initially, but this frequency is modified by the external varactor circuit. The particular transformer used must be evaluated so that the tap is closer to the grounded end than the gate end of the winding. I found the correct configuration by simple comparison of the d.c. resistance of the segments of the winding (B-A and B-C) referenced to the tap (0.3 Ω and 0.8Ω , respectively). This type of circuit was discussed in Part 1 of this article.

The tuning varactor has a maximum capacitance of 440 pF, but this value is a bit large for practical use. Therefore, a series capacitance, which is needed for d.c. blocking in any instance, is used to reduce the total capacitance. The same formula as above can be used for determining the value of series capacitance needed for making the circuit tune to any particular range.

The d.c. power supply was the same 12-V supply as used for the rest of the circuitry. An improved version might use a +9-V regulator to supply only the oscillator transistor. This design would prevent frequency pulling due to power supply noise or voltage variations caused by shifts in load current. If the receiver had used an incorporated audio power amplifier, rather than the outboard style used here (which has its own 12-V regulator), a separate regulator would have been indicated.

The output signal, when a 12-V d.c. power supply was used, was of the order of 800 mV_{pp}, so is within the drive range permitted by the SBL-1-1.

The IF output of the DBM (pins 3 and 4) is terminated in two circuits. First is capacitor C_2 and resistors R_1 and R_2. This network forms a 50-Ω match to the 50-Ω output of the DBM for high frequencies (a function of the capacitor). The $C_2/R_1/R_2$ network absorbs any residual LO and RF signal that makes it past the conversion process, while allowing the mixer to operate into its characteristic impedance. The second circuit terminating the DBM is an audio *LC* low-pass filter consisting of RFC_1 and C_3. This circuit passes only those audio frequencies in the normal communications audio bandwidth below 3 KHz.

The audio preamplifier for the receiver is a two-stage amplifier based on common n-p-n bipolar transistors (2N3904 or equivalent). Transistor T_1 is a common base amplifier. It is used because its low input impedance is a reasonable match to the filter and DBM. Transistor T_3 forms an emitter follower output amplifier. An active decoupler (T_2) is used in the power supply line of the amplifier.

Like the other receivers, this design suffered from a lack of audio gain, although this defect was without practical effect when only headphones were used for reception. If you would like to try improving the circuit, then try using an IC audio preamplifier between the output of T_3 and the input of the audio power amplifier stage. Also, a higher power audio amplifier might prove useful.

VLF direct conversion receiver

The very low frequency (VLF) bands are those frequencies below the medium wave AM broadcast band, i.e., below 540 KHz. A considerable amount of CW (morse code) and radio beacon activity is found in the VLF bands all over the world. In Europe, there is another broadcast band in the VLF region (145-280 KHz).

The circuit for the VLF DCR is shown in **Fig. 8**. This design is similar to Dillon, and also to one published in *The ARRL Handbook for Radio Amateurs (1993 Edition)*[6], although a number of component values are changed because of the changed frequency range.

The front-end of the circuit is an NE602 integrated circuit. In the test circuit, the input circuit is untuned, although tuning can be accomplished by connecting a capacitor from point 'A' in Fig. 8 to ground. Most readers will probably wish to use a combination of a varactor diode and a parallel fixed capacitor, rather than an actual air variable capacitor, as shown in the inset to **Fig. 8**. The capacitor marked C_x can be used to ensure the tuning range of the varactor and T_1.

The RF input transformer (Tr_1) and the local oscillator inductor (Tr_2) are 0.63-mH transformers intended for use as 455-KHz IF transformers. I used Toko RAN-10A6845EK, available in North America from Digi-Key (P.O. Box 677, Thief River Falls, MN 56701-0677; USA: Phone 1-800-344-4539 in USA and Canada) as part no. TK-1202.

The local oscillator circuit connected to pins 6 and 7 is a straightforward series-tuned Colpitts or Clapp design using the inductance of a 455-KHz IF transformer (see above) and a 440-pF voltage variable capacitance diode ('varactor'). I used the NTE618 or ECG618 service re-

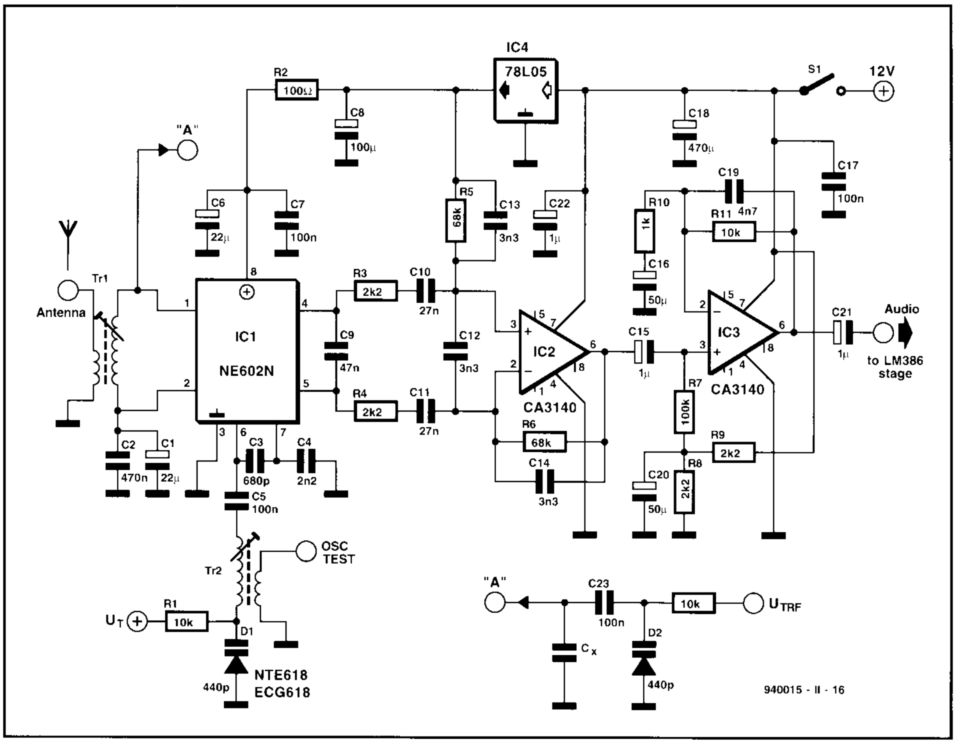


Fig. 8. Circuit for the VLF DCR receiver.

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placement types for this receiver.

A feature of using an IF transformer for the LO tuning coil is that the secondary of the coil can be used as a test point ('OSC TEST') for measuring the oscillator frequency.

The output network of the NE602 is the differential form seen in Dillon earlier. A 47-nF capacitor is connected across output pins 4 and 5 for AM and LO/RF suppression. A differential operational amplifier (IC_2) is used as an audio preamplifier to boost the signal level about 30 dB. The output of this amplifier is coupled through C_{15} to a non-inverting amplifer with a gain of 11. This stage was initially not used, but the audio output proved to be lower than I deemed comfortable when fed directly to the LM386 amplifier on the main chassis.

Both operational amplifiers are type CA3140 BiMOS devices, although it must be mentioned that the selection was based on supplies on-hand. There is no reason why any garden-grade op-amp would not work (the required audio bandwidth is only 3,000 Hz for SSB and even less for CW). A common 741 (which shares the pin-outs of the CA3140), or any other common op-amp will do nicely. Keep in mind, however, that the capacitors from pin no. 7 of both IC_2 and IC_3 are absolutely mandatory if CA3140 devices are used, and they must be connected as close to the body of the amplifier as possible.

The d.c. power distribution in this circuit is simple and straightforward. The +12 V supply voltage is applied directly to IC_2 and IC_3, which are both wired in the 'single-supply' configuration. In the case of IC_2 the amplifier is differential, so one of the resistors goes to +5 V rather than to ground, as is usual in such amplifiers. In the case of IC_3 there is a resistor voltage divider (R_8/R_9) used to bias the non-inverting input. Because of this form of operation, there will be a potential of about +6 V at output pin 6, so as a result a coupling capacitor (C_{21}) is needed to prevent interaction with the following stages.

This circuit performed reasonably well, but I felt that it lacked some of the sensitivity seen in the high frequency versions. In addition, there was severe interference from AM broadcast band signals at 560 KHz, 630 KHz and 1220 KHz (which station is very close to my home). A VLF RF preamplifier and proper shielding of both circuits solved the problem. I still intend to experiment with low-pass filters set to attenuate signals above 520 KHz as a means for eliminating the AM signals.

Conclusion

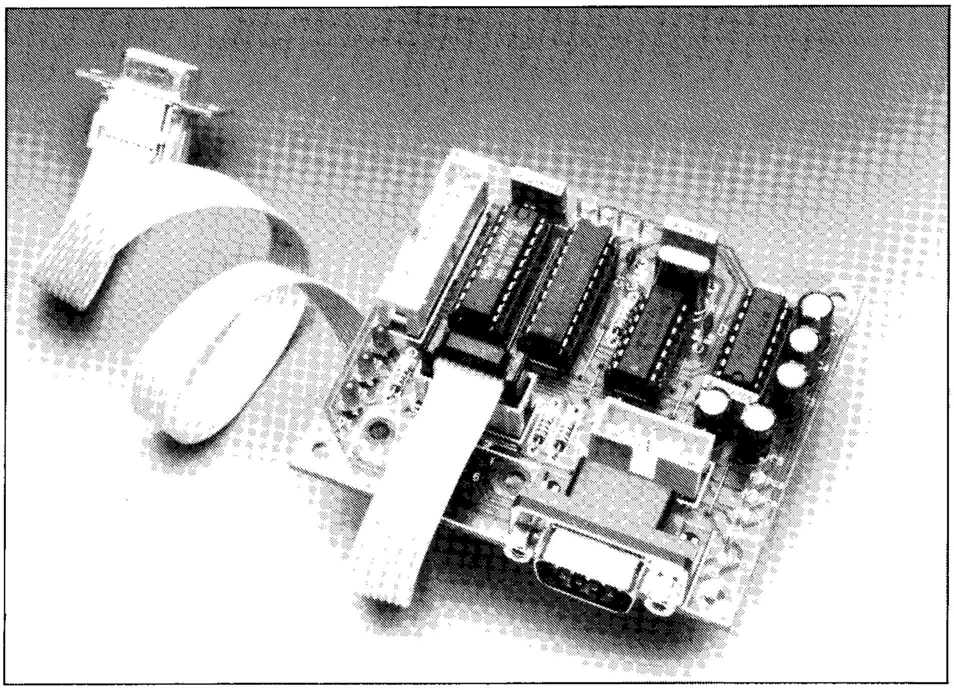
In the two instalments of this article we have toured the world of direct conversion receivers, examined their weaknesses and strengths and provided some examples of both circuit elements and complete circuits. What is left is for you to design and build a version of your own. ■

References and notes:

1. John Dillon, WA3RNC, 'The Neophite Receiver', *QST*, August 1988, pp. 14-19.
2. Roy W. Lewallen, W7EL, 'An optimized QRP Transceiver', *QST*, August 1980, pp. 14-19; Rick Campbell, KK7B, 'High-Performance Direct-Conversion Receivers', *QST*, August 1992, pp. 19-28.
3. Dillon (*op-cit.*)
4. 'NE602 Primer', Jospeh J. Carr, *Elektor Electronics*, January 1992, pp. 20-25.
5. Telephone conversation between the author and Mr. Dillon (Oct. 19, 1992)
6. 'The QRP Three-Bander CW Transceiver for 18, 21 and 24 MHz', *The ARRL Handbook for Radio Amateurs (1993 edition)*, American Radio Relay League (Newington, CT, 1992), pp. 30-19 to 30-25.

RS232 INTERFACE FOR UNIVERSAL BUS

Design by A. Rietjens



THIS is an RS232 extension card for the Universal I/O Interface for IBM PCs (Ref. 1). The circuit is based on the COM81C17 UART (universal asynchronous receiver/transmitter) from Standard Microsystem Corporation (SMC). This IC has an on-board programmable baud rate generator, which obtains its clock from a quartz crystal oscillator built around three gates in the 74HCT04 package.

The COM81C17 acts as an 8-bit read/write device on the bus. The RS232 handshaking is limited to the RTS-CTS (request to send - clear to send) pair, which will be adequate for most purposes. The status of these lines is indicated by two LEDs, D2 and D3. The $\overline{\text{INT}}$ (interrupt request) output of the IC is used as an activity indicator. The $\overline{\text{INT}}$ pin goes low when an 'enabled' condition has occurred in the status register, which can be read by the computer system via the bus.

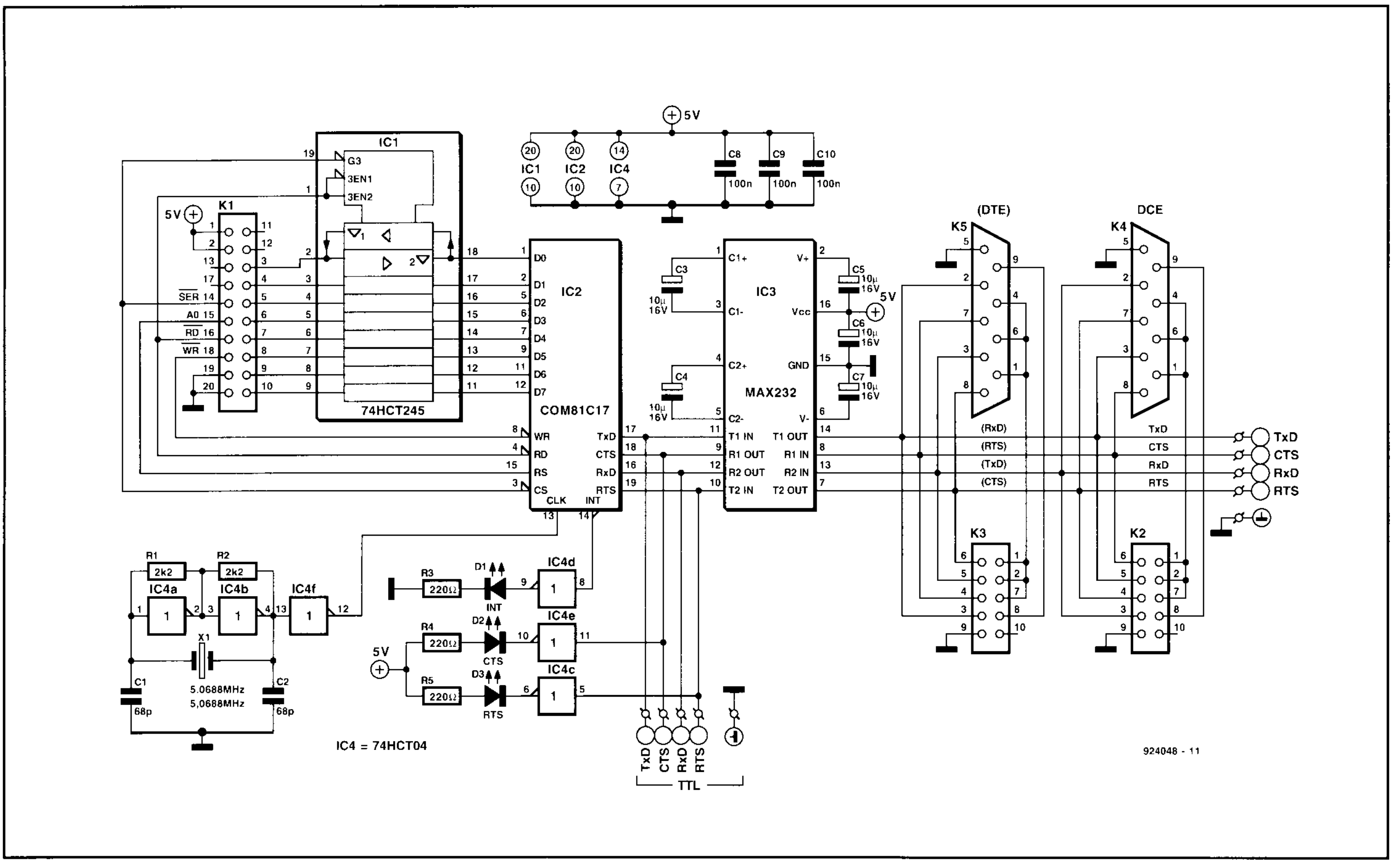


Fig. 1. Circuit diagram of the RS232 interface.

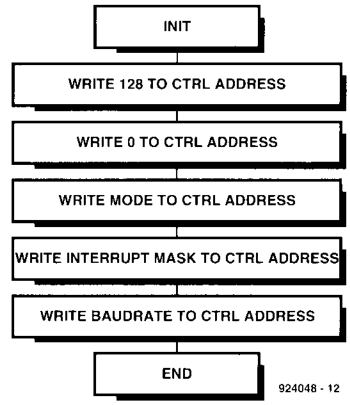

INIT
WRITE 128 TO CTRL ADDRESS
WRITE 0 TO CTRL ADDRESS
WRITE MODE TO CTRL ADDRESS
WRITE INTERRUPT MASK TO CTRL ADDRESS
WRITE BAUDRATE TO CTRL ADDRESS
END
924048 - 12

Fig. 2. UART initialization procedure flowchart.

Remarkably, the COM81C17 is housed in a 20-pin DIL enclosure. The fact that it has 20 pins fewer than the well-known AY3-1015D (former 'industry standard') UART is mostly due to the fact that all status signals nor mally found on a UART are available as bits in a status register, rather than logic levels on IC pins. These status signals include Tx shift register empty, overrun error, parity error, Rx buffer full, and a host of others. The baud rate selection pins are also omitted and re-

Bit	Function	Description
D0	CP1	pin 18 (CP1): 0 = CTS (in); 1 = input
D1	I/O (CP2)	pin 19 (CP2): 0 = output; 1 = input
D2	CP2	pin 19 (CP2): 0 = RTS (ouput);1 = input
D3	CLK	0 = internal divider; 1 = divide by 16
D4	PE	0 = no parity; 1 = parity enabled
D5	ODD	0 = even parity; 1 = odd parity
D6	# of data bits	0 = 7 databits; 1 = 8 databits
D7	# of stop bits	0 = 1 stop bit; 1 = 2 stop bits

924048-13

Fig. 3. UART MODE register programming.

Bit	Function	Description
D0	pin 18	input pin 18 (inverted)
D1	pin 19	input pin 19 (inverted); 0 if CP2 is output
D2	TX Shift Empty	1 if the transmit shift register is empty
D3	Parity Error	1 if parity error detected
D4	Overrun Error	1 if a character is overwritten before it has been fetched
D5	Frame Error	1 indicates wrong format received
D6	TX Buffer Empty	1 if the transmit buffer is empty
D7	RX buffer full	1 if the receive buffer is full

924048-14

Fig. 4. UART STATUS register programming.

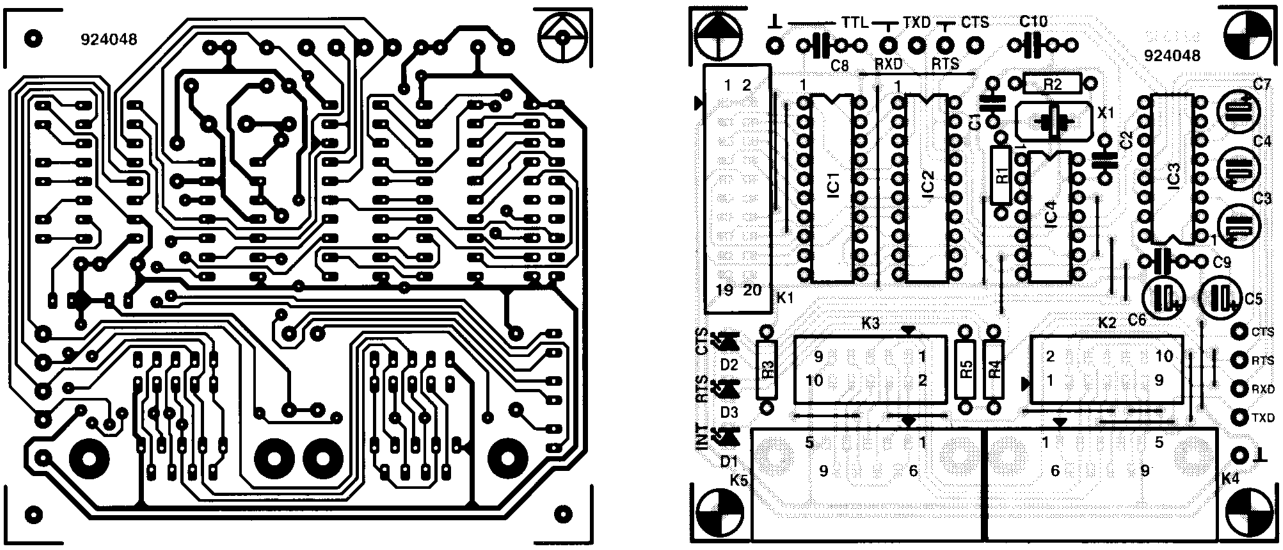


Fig. 5. Track layout and component monting plan of the circuit board designed for the RS232 interface (not available through the Readers Services).

COMPONENTS LIST

Resistors:
R1;R2 = 2kΩ2
R3;R4;R5 = 220Ω

Capacitors:
C1;C2 = 68pF
C3-C7 = 10µF 16V radial
C8;C9;C10 = 100nF

Semiconductors:
D1;D2;D3 = LED, red, 3mm
IC1 = 74HCT245
IC2 = COM81C17 *
IC3 = MAX232
IC4 = 74HCT04

* SMC, head office: 35 Marcus Street, Hauppage, NY 11788, USA. Telephone: (516) 273-3100. UK distributors: Golden Gate, Maidenhead, Telephone: (0628) 783631, Fax (0628) 71120, or Manhattan Skyline, Maidenhead, Telephone: (0628) 75851.

Miscellaneous:
K1 = 20-way boxheader.
K2;K3 = 10-way boxheader.
K4;K5 = 9-way angled PCB mount sub-D connector.
X1 = quartz crystal 5.0688 MHz.

placed by a 'software' equivalent.

Unfortunately, it is beyond the scope of this article to cover all programming functions of the COM81C17. For full details, you are referred to the datasheets supplied by SMC, or to Ref. 3. Some information is, however, presented to get you started: an initialisation procedure flowchart (**Fig. 2**), mode and status register overviews, (**Figs. 3** and **4**), the baud rate selection table (**Fig. 6**), and a BASIC program (**Fig. 7**). The latter provides a useful test for the hardware by echoeing transmitted characters. This requires K_3 or K_2 pins 3 and 5 (data) to be interconnected, and pins 4 and 6 (handshaking). Two jumpers are provided for this purpose. By the way, K_2 and K_3 are wired such that they can be connected directly to IDC-style D-connectors via lengths of flatcable (a straight pin1-to-pin 1 connection is used).

A MAX232 (with on-board negative voltage converter) is used in a standard configuration to interface the COM81C17 to the RS232 peripheral connected to K_4 or K_5. As shown in the circuit diagram, these two connectors allow the interface to behave like a DCE (data communication equipment) or a DTE (data terminal equipment). By 'tapping' the connections between the COM81C17 and the MAX232, a TTL-level serial interface is created, which may be used when RS232 levels are not required.

Finally, the addressing of cards connected to the universal bus, and the rules that apply to implementing read/write functions at one address, are discussed in Ref. 2. ■

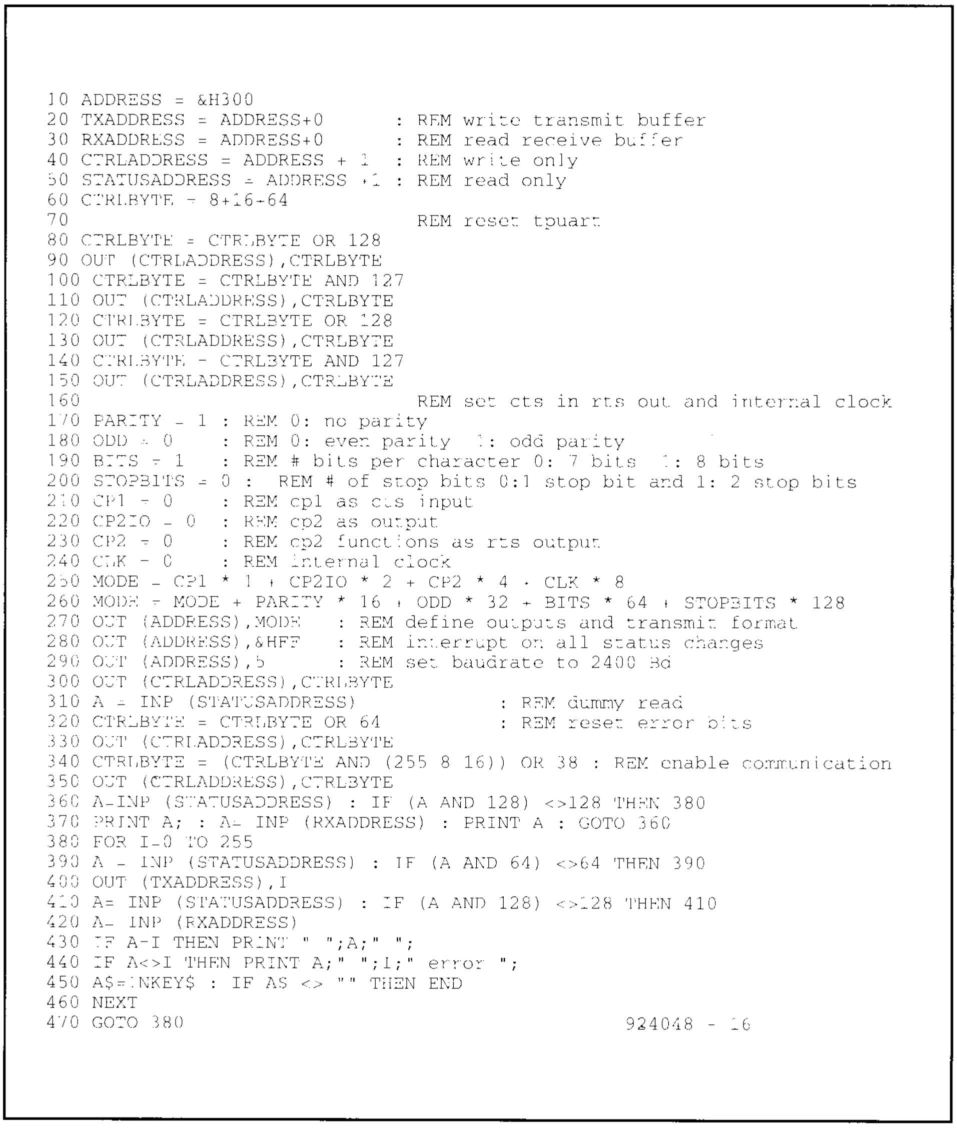
References:

1. 'Universal I/O interface for IBM PCs and compatibles', *Elektor Electronics* May 1991.
2. 'Optocard for universal PC I/O interface', *Elektor Electronics* July/August 1992.
3. Databook 4: peripheral chips. *Elektor Electronics* publication.

D3 - D0	Baud rate
0000	50
0001	110
0010	134.5
0011	150
0100	300
0101	600
0110	1200
0111	1800
1000	2000
1001	2400
1010	3600
1011	4800
1100	7200
1101	9600
1110	19200
1111	38400

924048-15

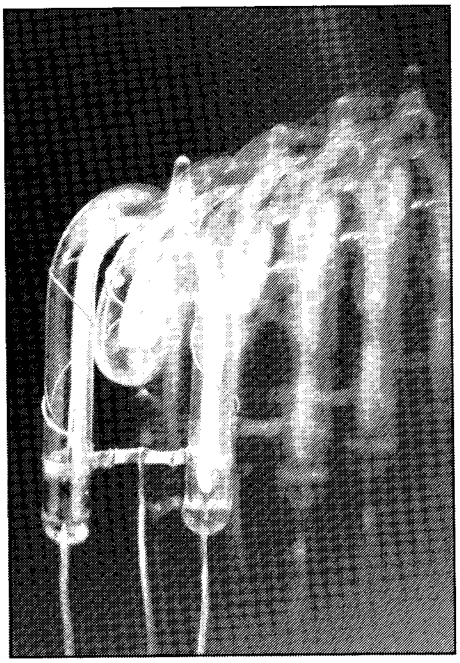
Fig. 6. UART baud rate selection.



```
10 ADDRESS = &H300
20 TXADDRESS = ADDRESS+0        : REM write transmit buffer
30 RXADDRESS = ADDRESS+0        : REM read receive buffer
40 CTRLADDRESS = ADDRESS + 1    : REM write only
50 STATUSADDRESS = ADDRESS +1   : REM read only
60 CTRLBYTE = 8+16+64
70                                REM reset tpuart
80 CTRLBYTE = CTRLBYTE OR 128
90 OUT (CTRLADDRESS),CTRLBYTE
100 CTRLBYTE = CTRLBYTE AND 127
110 OUT (CTRLADDRESS),CTRLBYTE
120 CTRLBYTE = CTRLBYTE OR 128
130 OUT (CTRLADDRESS),CTRLBYTE
140 CTRLBYTE = CTRLBYTE AND 127
150 OUT (CTRLADDRESS),CTRLBYTE
160                               REM set cts in rts out and internal clock
170 PARITY = 1 : REM 0: no parity
180 ODD = 0    : REM 0: even parity  1: odd parity
190 BITS = 1   : REM # bits per character 0: 7 bits  1: 8 bits
200 STOPBITS = 0 :  REM # of stop bits 0:1 stop bit and 1: 2 stop bits
210 CP1 = 0    : REM cp1 as cts input
220 CP2IO = 0  : REM cp2 as output
230 CP2 = 0    : REM cp2 functions as rts output
240 CLK = 0    : REM internal clock
250 MODE = CP1 * 1 + CP2IO * 2 + CP2 * 4 + CLK * 8
260 MODE = MODE + PARITY * 16 + ODD * 32 + BITS * 64 + STOPBITS * 128
270 OUT (ADDRESS),MODE    : REM define outputs and transmit format
280 OUT (ADDRESS),&HFF    : REM interrupt on all status changes
290 OUT (ADDRESS),5       : REM set baudrate to 2400 Bd
300 OUT (CTRLADDRESS),CTRLBYTE
310 A = INP (STATUSADDRESS)           : REM dummy read
320 CTRLBYTE = CTRLBYTE OR 64         : REM reset error bits
330 OUT (CTRLADDRESS),CTRLBYTE
340 CTRLBYTE = (CTRLBYTE AND (255 8 16)) OR 38 : REM enable communication
350 OUT (CTRLADDRESS),CTRLBYTE
360 A=INP (STATUSADDRESS) : IF (A AND 128) <>128 THEN 380
370 PRINT A; : A= INP (RXADDRESS) : PRINT A : GOTO 360
380 FOR I=0 TO 255
390 A = INP (STATUSADDRESS) : IF (A AND 64) <>64 THEN 390
400 OUT (TXADDRESS),I
410 A= INP (STATUSADDRESS) : IF (A AND 128) <>128 THEN 410
420 A= INP (RXADDRESS)
430 IF A=I THEN PRINT " ";A;" ";
440 IF A<>I THEN PRINT A;" ";I;" error ";
450 A$=INKEY$ : IF A$ <> "" THEN END
460 NEXT
470 GOTO 380                                    924048 - 16
```

Fig. 7. BASIC program to demonstrate the operation of the RS232 interface.

STROBOSCOPE LIGHT



A flash tube control circuit is described which is suitable for playful as well as serious applications. The unit has a flash frequency of up to 100 Hz, and may also be triggered by an external source.

Design by T. Giesberts

STROBOSCOPE lights are very much in vogue these days, and can be seen in discotheques and shop windows, but also in the hands of the car mechanic (actually it is hard not the see them, the light of the more powerful units having an almost blinding and dazzling effect).

Where most stroboscope lights have a flash rate of between 1 Hz and 10 Hz, the present design reaches a maximum of about 100 Hz. Although such a high frequency is pretty exacting on the components used, it does give the stroboscope a much wider application area. Apart from creating exciting light effects, the circuit may also be used for mechanical adjustments (car ignition systems), or for advanced studies of human movement (particularly in 'professional' sports training and physiotherapy).

Block diagram

The block diagram in **Fig. 1** should enable you to get an understanding of the operation of the circuit without having to know the exact function of each and every component. The dashed block in the centre of the drawing is the flash circuit proper. The flash tube, La, is triggered in a conventional manner. When the tube is quenched, triac Tri acts as an opened switch, so that capacitor C_b is charged by the power supply via resistor R_b (and R_a). When the triac is triggered and starts to conduct, the right-hand side of C_b is effectively taken to ground, whereupon this capacitor discharges itself abruptly via transformer Tr. The result is a high voltage pulse which is stepped up even further by the ignition transformer. The pulse fires the flash tube, which remains lit until capacitor C_a is discharged. Next, the tube goes out, the capacitors are recharged, and the circuit waits for a new trigger pulse for the triac.

So far, it all looks pretty simple. However, there are a few snags which have given rise to a some interesting circuit details. Since it was desired to have a controlled amount of energy per flash, the circuit operates in such a way that the flash tube must discharge a capacitor, the value of which allows the amount of energy to be controlled fairly accurately.

An unexpected problem is caused by the charging of capacitor C_a. If the circuit is to achieve a high flash rate whilst guaranteeing the maximum possible flash energy, the capacitor must be charged very rapidly. This, in turn, requires a fairly small value of resistor R_a. An obvious disadvantage of the low value of R_a is that a relatively high current flows through the tube once this has been fired. This is undesirable, and must be avoided since it can cause thermal overloading of the tube. The problem is solved by adding (semiconductor) switch S, which remains closed during the charging phase, and is opened as soon as an trigger pulse arrives. Consequently, the supply is disconnected from the flash tube during the actual flash.

Two monostable multivibrators are used to supply the trigger pulses, and control switch S. MMV_2 supplies the trigger pulses, while MMV_1 acts as a self-starting oscillator which determines the flash rate. First, a charge cycle is started for C_a, via switch S. This is immediately followed by an ignition pulse for the triac. Controls P_1 and P_2 allow the charging time and the flash repeat time to be adjusted respectively. In practice, things are a little more complicated than described here. A more detailed description will be given further on.

Finally, a switch is shown which enables the flashing to be stopped. Also, provision has been made to drive MMV_1 from an external oscillator. In that case, MMV_1 functions as a monostable multivibrator rather than an oscillator.

Practical design

The circuit diagram of the stroboscope light, **Fig. 2**, is a worked out version of the block diagram discussed above. Let us first do a quick tour around the various sub-circuits. The flash circuit proper is easily found because it is drawn in the direct vicinity of the flash

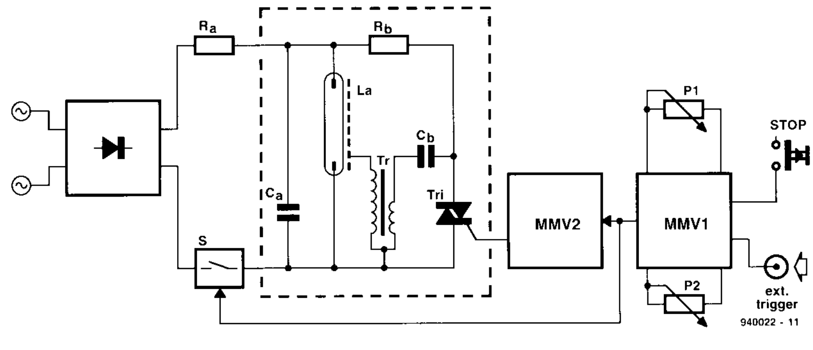


Fig. 1. Apart from a standard flash tube circuit (shown in dashed outline), the stroboscope also contains a power supply and a control circuit. When the tube flashes, the charge current which flows into C_a is interrupted by electronic switch S.

tube, La$_1$, transformer Tr$_1$ and triac Tri$_1$. The supply is roughly formed by the part around D$_1$-D$_4$ and C$_1$-C$_2$, while the drive circuit consists mainly of IC$_{1a}$ and IC$_{1b}$. Switch S$_1$ functions as the 'stop' control; K$_2$ is the external oscillator input, and switch S shown in the block diagram is actually formed by a transistor, T$_3$.

The supply voltage is taken from the mains, and rectified. This causes a direct voltage of about 340 V across parallel connected high-voltage electrolytic capacitors C$_1$ and C$_2$. The flash capacitor, C$_4$-C$_8$, is charged via four parallel connected 10-watt resistors, R$_5$-R$_8$. Note that the flash capacitor consists of five parallel-connected low-loss solid capacitors for pulsed applications (Siemens MKP types) — an electrolytic type with an equivalent value (approx. 11 µF) would be unsuitable considering the highest flash rate of about 100 Hz.

The flash tube, La$_1$, requires a firing voltage of between 4 and 6 kV. This voltage is supplied as a short pulse by the secondary winding of transformer Tr$_1$ when C$_9$ discharges. The same pulse, however, also causes a considerable current surge through the primary winding of Tr$_1$. Consequently, a relatively high power triac is used — in this case, a TIC263M.

The drive signals for the triac (firing pulse) and the charging switch, T$_3$, are supplied by IC$_1$, a double MMV type 74HC221. This IC was chosen because it has some hysteresis on the positive trigger input. This affords a high degree of noise immunity, while the circuit is also capable of accepting extremely low-frequency trigger pulses. After the monotime of IC$_{1a}$ has elapsed (adjustable with P$_1$), T$_3$ is switched off via pin 13. This causes the charging of C$_4$-C$_8$ to be stopped. At the same time, however, IC$_{1b}$ is triggered. The MMV responds by supplying a pulse which is long enough to trigger the triac via T$_1$.

To prevent the flash tube from being overloaded while still achieving a reasonably high flash rate, the charging time control (P$_2$) and the flash rate control (P$_1$) are arranged to interact. This is achieved by adding the monotime set with P$_2$ to the time set with P1. In this way, P$_2$ also determines the flash frequency. P$_1$ allows a maximum frequency of about 50 Hz to be set, which may be increased to 100 Hz by adjusting P$_2$. By virtue of the relatively short charging time, the energy fed to the flash tube remains more or less constant. At low frequencies, P$_2$ has a smaller effect on the frequency, and causes a small variation in brightness when the potentiometer is turned. If a flash tube is used which is different from the one stated in the components list, it may even happen that the trigger voltage drops below the firing threshold, and the tube starts to flash irregularly when P$_2$ is turned.

The 'stop' press-key is formed by S$_1$. If you use a push-to break switch in this position, the stroboscope flashes as long as you keep the key pressed. Alternatively, a normal on/off switch enables the circuit to be switched on and off permanently. Components D$_8$

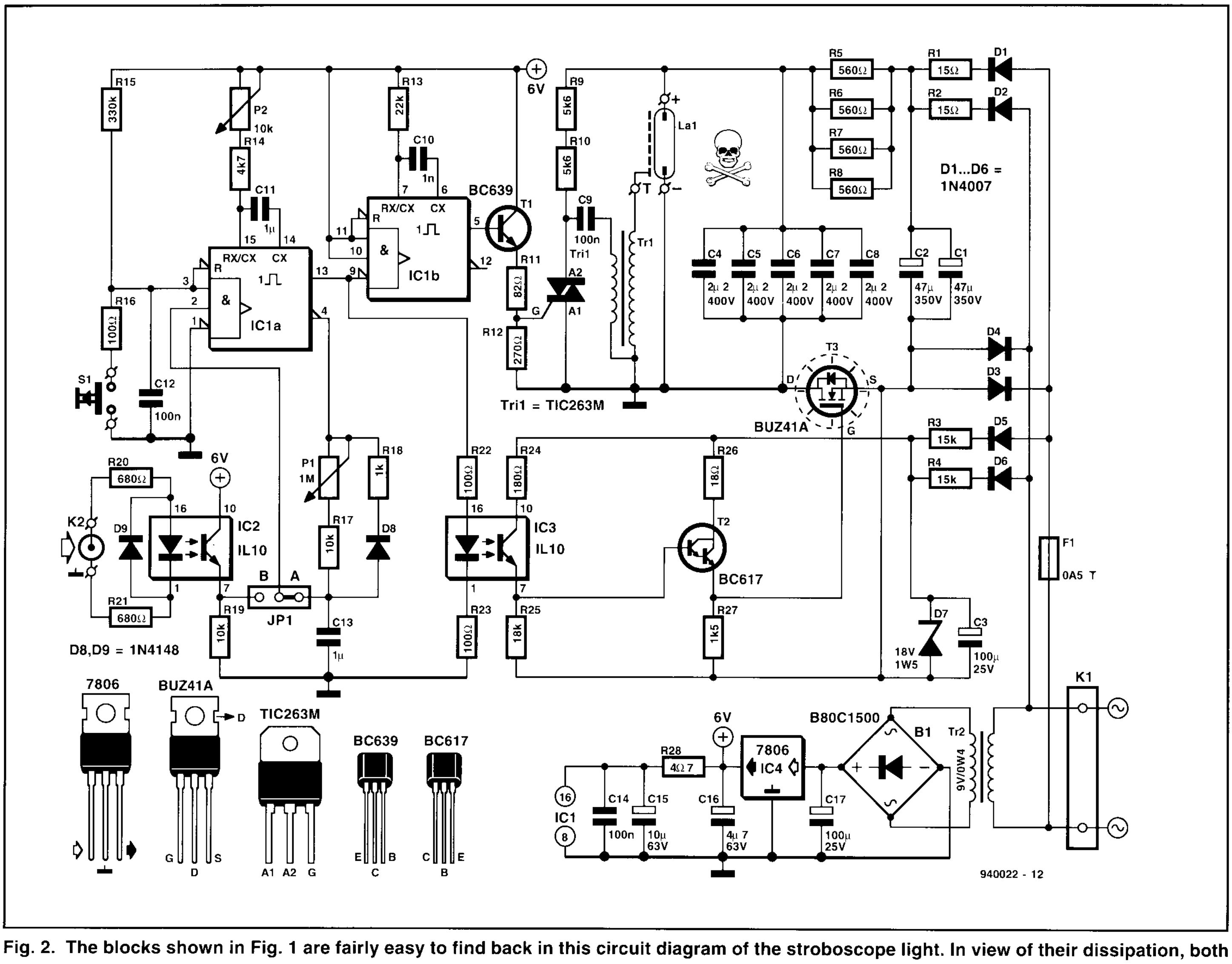


Fig. 2. The blocks shown in Fig. 1 are fairly easy to find back in this circuit diagram of the stroboscope light. In view of their dissipation, both the charging capacitor and the associated series resistor consist of a number of parallel connected components (capacitors C4-C8 and resistors R5-R8 respectively).

and R_{18} are added to enable C_{13} to be discharged during the period set with P_2 and R_{14}-C_{11}.

Opto-isolators

Apart from the electronics already discussed, **Fig. 2** also shows two opto-isolators, IC_2 and IC_3. The first serves to afford electrical safety by creating isolation between the input of the external trigger oscillator (K_2) and the rest of the circuit. Jumper JP_1 allows you to select between internal and external triggering. If you select jumper position 'B', IC_{1a} operates as an MMV with P_1 effectively disabled. D_9 protects the LED in the opto-isolator, and limits the reverse voltage to about 0.7 V.

The second opto-isolator, IC_3, has a quite different function. The controlling of power FET T_3 requires an additional circuit because a voltage difference of some 320 V occurs between C_4-C_8 and the negative terminals of C_1 and C_2. Consequently, the gate of T_3 would have to be driven (by IC_{1a}) with a potential which is 300 V higher! Obviously, that is a totally impractical requirement. Fortunately, the problem can be solved in a fairly simple way by adding an opto-isolator whose phototransistor is fed from a separate supply line. This voltage is derived from the mains by rectifier D_5-D_6, current limiters R_3-R_4, smoothing capacitor C_3, and stabilizer D_7. Darlington transistor T_2 acts as a buffer between the phototransistor in IC_3 and the gate of T_3.

Still on the subject of supply lines, IC_1 and the triac drive circuit obviously require a suitable supply voltage also. Since the current consumption of the relevant components is too high to enable it to be supplied directly by the mains at reasonable efficiency, a miniature (0.35-VA) transformer is used (Tr_2). A couple of electrolytic capacitors and a 7806 (IC_4) are added to give a small 6-V d.c. power supply.

Construction

Before you start building the present project, seriously consider the following point regarding electrical safety. **Most parts in the circuit are at mains potential, and are, therefore, extremely dangerous to touch. Never touch any part while the circuit is connected to the mains. Always disconnect the circuit from the mains before doing any measurement or adjustment.** Also note that the high-voltage capacitors retain their charge for quite a while after the circuit is disconnected from the mains, so be extremely careful.

The artwork of the printed circuit board designed for the stroboscope light is shown in **Fig. 3**. Unfortunately, this PCB is not available ready-made

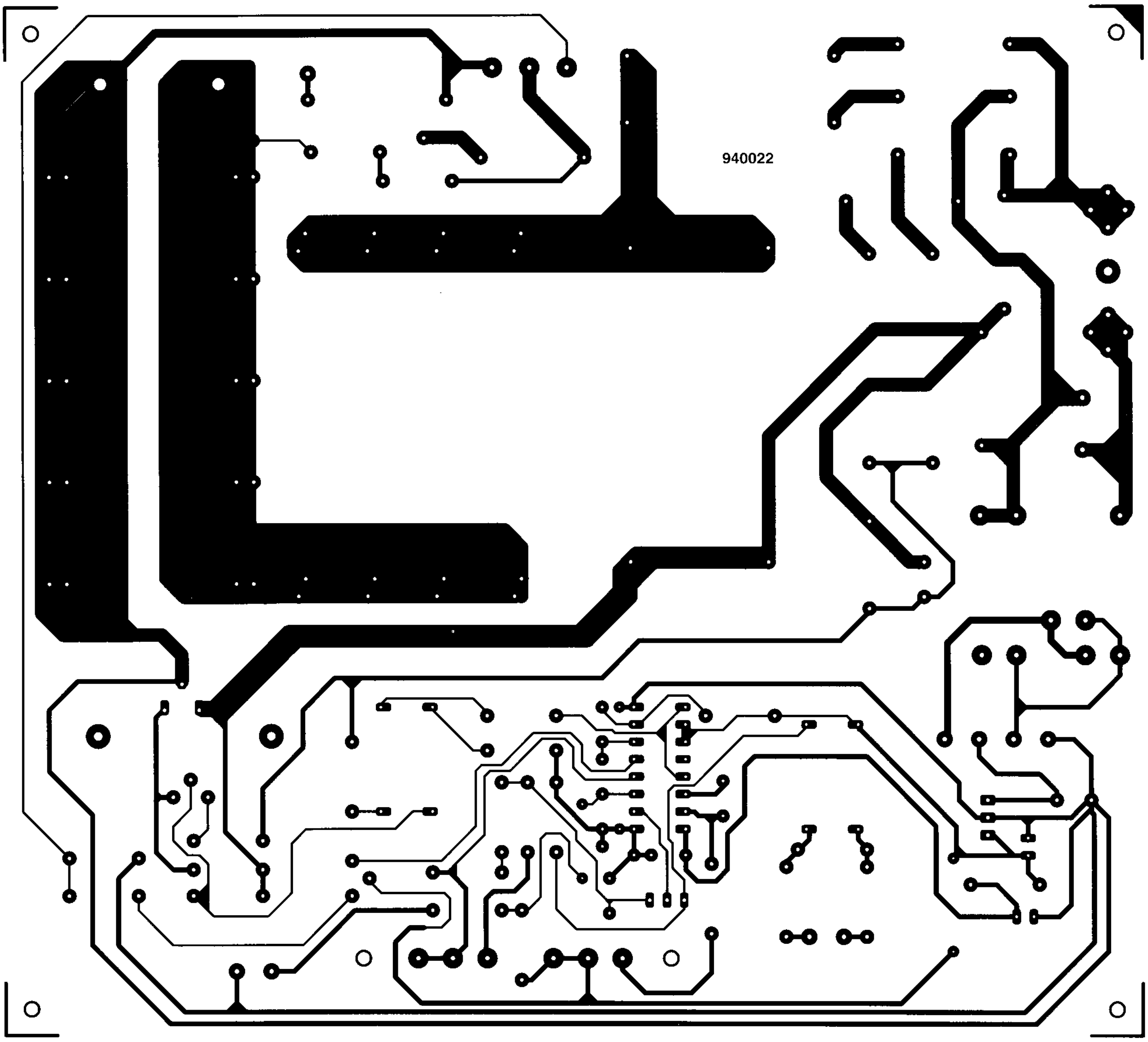


Fig. 3. The PCB is marked by its spacious track pattern between C1-C2 and La1. Always keep in mind that most tracks on the board are

through our Readers Services, so you have to etch and drill it yourself (alternatively, you may want to have it made for you). The track layout is fairly 'spacious'. The copper tracks in the section roughly between C_1 and Tr_1 are very wide because of the high currents they carry. The connections for potentiometers P_1 and P_2, socket K_2, switch S_1 and the jumper are located at the front edge of the board. The rear edge has the connections for the flash tube, while the fuseholder for F_1, and the PCB terminal block for connecting the mains cable (K_1), are found at the left-hand side edge.

A few notes must be made regarding the construction of the unit. Resistors R_5 through R_8 must be mounted at a height of about 1 cm above the board to allow for their dissipation. Transistor T_3 must be mounted on a fairly large heat-sink using an insulating washer and a bush. Given the current through the flash tube, and its heat dissipation, the connection to the contacts provided on the board must be solid. For the prototype, spade terminals were used of the type found in cars. If it is desired to fit the tube at some distance from the board, mains rated cable should be used with good insulation properties and a minimum cross-sectional area of 2.5 mm^2.

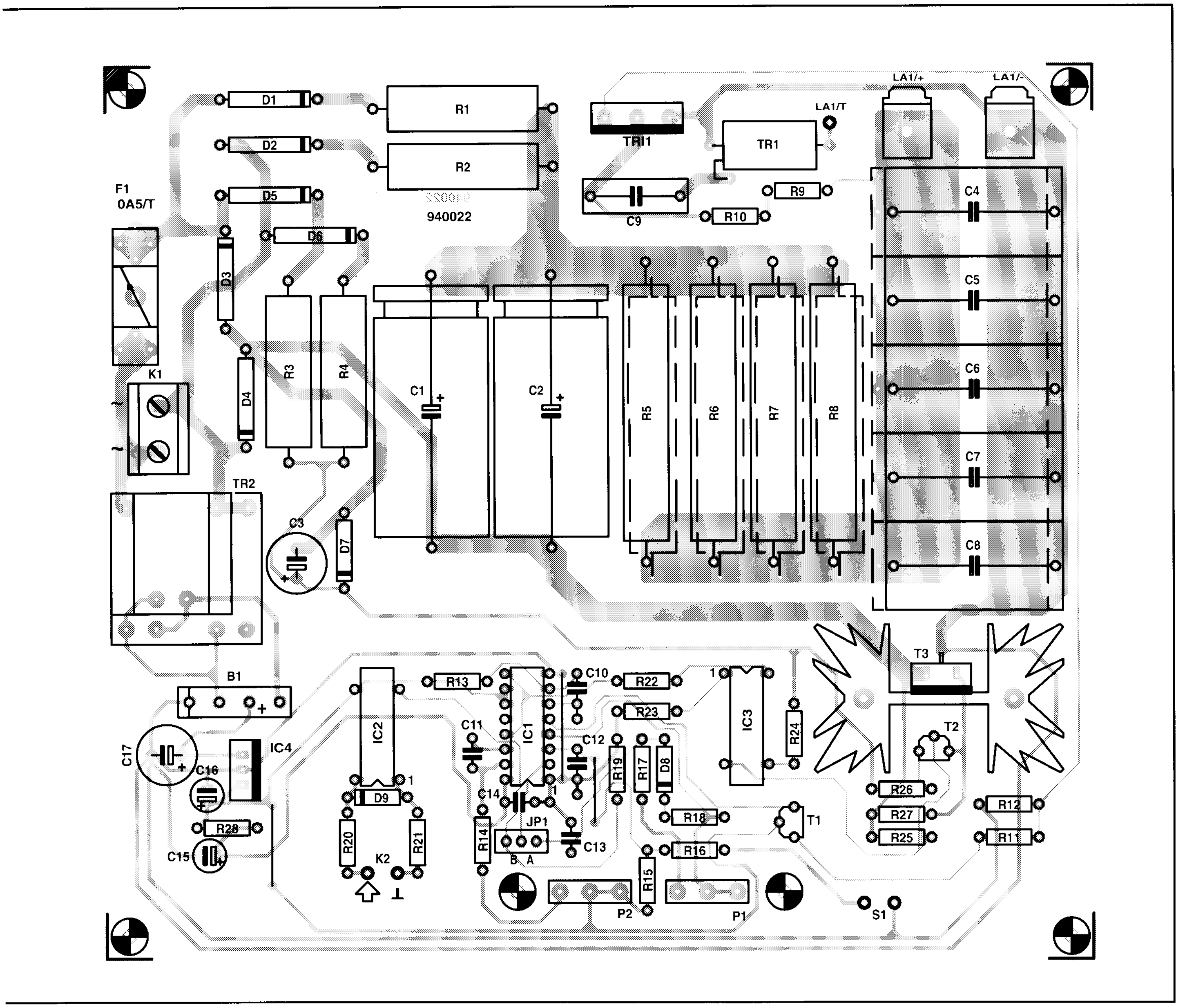
The potentiometers must be types with a plastic spindle. They are fitted direct on to the board using small brackets. The PCB layout is such that various types of mains transformer can be used. Voltage regulator IC_4 is only lightly loaded. Consequently it dissipates little heat, and can make do without a heat-sink.

Once all components are fitted on to the board, run a very careful inspection on your solder work. Also check the polarity of the high voltage electrolytics, C_1 and C_2, and diodes D_1-D_4. The photograph in **Fig. 4** shows the prototype of the PCB after completing the solder work and the visual inspection.

A case for a case

The choice of a suitable enclosure for the circuit will depend greatly on the nature of the application. One option is to fit the flash tube behind a window, in the same case as the control circuit. Alternatively, you may want to mount the tube in a separate, duly insulated, case, and connect it to the control circuit via a length of insulated cable. For the sake of safety, the control circuit must be mounted in a metal case which is connected to the mains earth line via a good quality mains socket.

Another point that deserves your attention is the heat developed by some parts of the circuit, notably R5-R8, T3 and the flash tube. Keep in mind that



extremely dangerous to touch since they are at mains potential or even higher.

COMPONENTS LIST

Resistors:
R1;R2 = 15Ω 5W
R3;R4 = 15kΩ 5W
R5-R8 = 560Ω 10W
R9;R10 = 5kΩ6
R11 = 82Ω
R12 = 270Ω
R13 = 22kΩ
R14 = 4kΩ7
R15 = 330kΩ
R16;R22;R23 = 100Ω
R17;R19 = 10kΩ
R18 = 1kΩ
R20;R21 = 680Ω
R24 = 180Ω
R25 = 18kΩ
R26 = 18Ω
R27 = 1kΩ5
R28 = 4Ω7
P1 = 1MΩ log. (all ABS)
P2 = 10kΩ lin. (all ABS)

Capacitors:
C1;C2 = 47µF 350V (Siemens B43050-C4476-T)[1]
C3;C17 = 100µF 25V radial
C4-C8 = 2µF2 400V MKP (Siemens B32650-K4225-J)[1]
C9 = 100nF 400V MKP (Siemens B32650-K4104-J)[1]
C10 = 1nF
C11;C13 = 1µF, pitch 5mm
C12,C14 = 100nF
C15 = 10µF 63V
C16 = 4µF7 63V

Semiconductors:
B1 = B80C1500
D1-D6 = 1N4007
D7 = 18V 1W5 zener diode
D8,D9 = 1N4148
T1 = BC639
T2 = BC617
T3 = BUZ41A
IC1 = 74HC221
IC2,IC3 = IL10 (Siemens)[1] or CNY65 (Telefunken)
IC4 = 7806
Tri1 = TIC263M

Miscellaneous:
JP1 = 3 PCB pins.
K1 = 2-way PCB terminal block, pitch 7.5mm.
K2 = BNC socket.
S1 = Press-key w. make contact, mains rated.
F1 = Glass fuse 0.5A slow, w. PCB holder.
La1 =Xenon flash tube, e.g., FT-152G (Display Elektronika)[2].
Tr1 = 6-kV trigger transformer, e.g. 58 16 15 (Conrad)[3].
Tr2 = Mains transformer 2x9V, e.g, 196-757 (Electromail)[4] . For 220V mains: BV 20 0009 (Hahn), 1090007M (Velleman) or EE20-0.35VA (Conrad).
Heat-sink for T3.
Two spade terminals, screw-mount.

[1] ElectroValue, Unit 3, Central Trading Estate, Staines TW18 4UX. Te. (0784) 442253, fax (0784) 460320.
[2] Display Elektronika, Coloradodreef 18, NL-3665 BT, Utrecht, Holland, Tel. (+31) 30 611855, fax (+31) 30 622024.
[3] Conrad Electronic Nederland BV, P.O. Box 12, NL-7500 AA Enschede, Holland. Tel. (+31) 53 282000, fax (+31) 53 283075.
[4] Electromail, P.O. Box 33, Corby, Northants NN17 9EL, England. Tel. (0536) 204555, fax (0536) 405555.

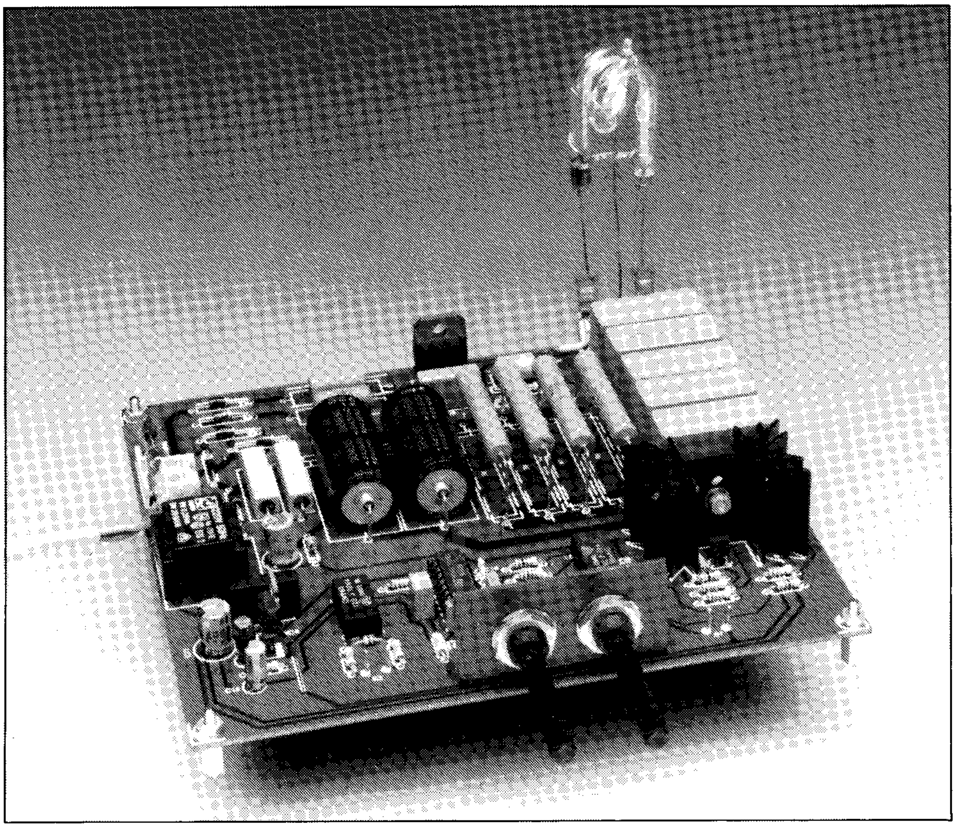


Fig. 4. Finished printed circuit board with components loaded, ready for mounting into a metal enclosure.

the heat dissipation increases with the flash rate. Some means of ventilation must, therefore, be provided in the case. If the flash tube and the control board are fitted in a single case, a small fan is probably no luxury.

Finally, a word about the flash tube. These devices come in many sizes and specifications. Many of these are suitable for use in the present circuit, and there is no need to insist on using the one mentioned in the parts list (FT-152G), although this has been tested by us, and is known to give good results even at the highest flash rate. The temperature of the tube rises with the repeat rate set with the potentiometers. This on its own causes thermal problems with some tubes. Unfortunately, a related problem then arises; the ignition voltage increases with the device temperature, so that the tube does not light at every discharge. In particular as regards too small tubes, be warned that the highest frequency that can be generated by the circuit may result in too much energy being fed to the tube. This may cause the lifetime of the tube to be reduced considerably. ■

READERS' CORNER

CORRECTIONS

Liquid crystal displays
(February 1994 - p. 46)

Some pin numbers of IC_1 in Fig. 1 are shown incorrectly: pins 1 and 3, and pins 4 and 6, should be interchanged.

Telephone-controlled switch
(January 1994 - p. 58)

The address of Chesilvale Ltd. in the Components List on p. 60 should read:
Unit 3, Maes Glas Industrial Estate,
Newport, Gwent NP9 2NN;
Telephone +44 (0)633 223 552;
Fax +44 (0)603 223 948.

PRODUCT NEWS

Parallel port data acquisition offers high performance at low cost

New from Computer Instrumentation Ltd is the 'Parallel Pad' Data Acquisition System. Connected to a PC or Notebook computer parallel port, the 'Parallel Pad' achieves data acquisition at up to 100 kHz using a 12 bit converter with programmable ranges from ±10 mV to ±10 V.

An additional screw terminal block assembly may be plugged in providing 8×4 wire inputs suitable for a range of sensors including thermocouples, PRTs, accelerometers, mV signals and mA signals. Also provided are 32 programmable logic input/output channels and two counter/timers for frequency measurements, and so on.

Powered from the mains, or its own internal batteries, the unit is suitable for laboratory, factory or field use. A stand-alone (wake/sleep) data logghing mode then allows the notebook to be taken home. leaving the 'Parallel Pad' to collect data under battery power.

At £445·00, the basic cost includes a range of software drivers for BASIC, Pascal, C, and Visual BASIC for Windows, together with versions of Computer Instrumentation's SoftScope and Data Logging software.

Computer Instrumentation Ltd, Bld. no. 3
Woods Way, Goring, Worthing, England
BN12 4QY;
Telephone +44 (0)903 700 755;
Fax +44 (0)903 700 788.

Let Maplin Electronics help beat the fuel VATman

With the imposition of VAT on fuel to come into operation this month, it is not too soon to be planning ways and means of reducing the household and office fuel bills. One sure fire way is the implementation of fuel saving devices and controllers and it is here that Maplin Electronics can help everyone to save money. The new Maplin catalogue (see back cover) features many cost effective, value for money products designed with energy saving in mind.

New from Maplin is the **24-hour Programmable Timer** which has many security and energy saving uses. Lights and radio can be timed to switch on and off throughout the day and night for security purposes, and a random program mode allows lights to be switched at random for even higher protection.

Also from Maplin is the **Digital Timeswitch** comprising a battery powered clock with LC display which controls power throughout to a mains outlet. The unit plugs into a standard wall socket in which position the display and controls are easily seen.

Also new is the **7-day Immersion Heater Controller**, a wall mounted unit that provides economical and convenient control of electric immersion heater systems. Easily programmable, the controller allows up to seven on/off switching programmes with automatic everyday allocation, providing up to 49 on/off settings per week. An optional 'boost' facility enables instant override for one or two hour periods.

Also available is a **Room Thermostat** which features easy-to-use controls for all kinds of heating system. Mounted on the wall, this thermostat, once set to the required temperature, will automatically trigger the heating system to come on and go off in order to maintain that temperature. This unit can be linked to any pump to control gas, solid fuel or oil fired central heating, warm air and electric underfloor or ceiling systems. The unit includes an 'accelerator' which reacts quickly to changes in room temperature so as to maintain an even level.

All items available from Maplin shops (including the new Northampton, Milton Keynes and Slough stores) or by mail order. (Please note: there is a £1·40 charge levied on every mail order to go towards the cost of handling and packing. On large, fragile or heavy items, an additional charge is made to contribute towards the cost of carriage, up to a maximum of £5·70 per order).

The Maplin 1994 Catalogue is available at £2·95 from W H Smith, R S McColl (Scotland) and local Maplin shops. Mail order price UK: £3·45.

Maplin Electroncis, PO Box 3,
Rayleigh, England SS6 8LR; Telephone:
Sales +44 (0)702 554 161;
Enquiries +44 (0)702 552 911;
Fax +44 (0)702 553 935.

COMPONENT RATINGS

In resistor and capacitor values, decimal points and large numbers of zeros are avoided wherever possible. Small and large values are usually abbreviated as follows:

p (pico-) = 10^{-12}
n (nano-) = 10^{-9}
µ (micro-) = 10^{-6}
m (milli-) = 10^{-3}
k (kilo-) = 10^{3}
M (mega-) = 10^{6}
G (giga-) = 10^{9}

Note that nano-farad (nF) is the international way of writing 1000 pF or 0.001 µF. Resistors are $^{1}/_{3}$ watt, 5% metal film types unless otherwise specified.

The direct working voltage of capacitors (other than electrolytic or tantalum types) is assumed to be ≥60 V. As a rule of thumb, a safe value is about 2× direct supply voltage.

Direct test voltages are measured with a 20 kΩ/V meter unless otherwise specified.

Mains (power line) voltages are not listed in the articles. It is assumed that our readers know what voltage is standard in their part of the world.

Readers in countries that use 60 Hz supplies, should note that our circuits are usually designed for 50 Hz. This will not normally cause problems, although if the mains frequency is used for synchronization, some modification may be required.

The international letter symbol '*U*' is used for voltage instead of the ambiguous '*V*'. The letter V is reserved for 'volts'.

The size of a metric bolt or screw is defined by the letter M followed by a number corresponding to the overall diameter of the thread in mm, the × sign and the length of the bolt or screw, also in mm. For instance, an M4×6 bolt has a thread diameter of 4 mm and a length of 6 mm. The overall diameter of the thread in the BA sizes is: 0 BA = 6.12 mm; 2 BA = 4.78 mm; 4 BA = 3.68 mm; 6 BA = 2.85 mm; 8 BA = 2.25 mm.

High sensitivity frequency counter/finder

Quantek Electronics have introduced a high sensitivity pocket size frequency counter/finder, Model FC2000, capable of measuring frequencies from 1 MHz to 2.4 GHz.

Conventional frequency counters typically have a specified sensitivity of 10 mV, whereas that of the FC2000 is <1 mV between 10 MHz and 850 MHz and is typically 225 µV at 150 MHz. This enables the FC2000 to be used for measuring transmitted radio frequency signals as well as for laboratory bench measurements.

The compact and rugged design of the FC2000 makes it ideally suited for use by field service engineers, radio amateurs, scanning receiver owners for frequency finding, and counter surveillance operators.

The FC2000 has a bright 8-digit LED display, two gate times, hold function, charge and gate LEDs, 50-Ω BNC input, internal 700 mAh NiCd batteries, and is supplied complete with a.c. mains adaptor/charger and telescopic BNC antenna.

The FC2000 costs £119 + £5 p&p and is available direct from Quantek Electronics, 3 Houldey Road, Birmingham, England B31 3HL. Telephone +44 (0)21 411 1821; Fax +44 (0)21 411 2355.

Mitsubishi 38000 Series of 8-bit microcontrollers from Highland Technology

Available from Highland Technology is the Mitsubishi 38000 Series of 8-bit microcontroller, which includes general-purpose types as well as devices designed specifically for controlling vacuum fluorescent and liquid crystal displays.

The controllers are designed for ease of use and versatility, with ROM, RAM, I/O and control registers all within the same address space to allow data transfer and operation to be performed by common instructions.

The devices can operate in either single-chip mode, accessing only internal memory, or in expanded and external memory modes in which I/O ports become address, data and control lines, mapping external memory and peripherals.

Further details from Highland Technology, Albert Drive, Burgess Hill, England RH15 9TN. Telephone +44 (0) 444 236 000; fax +44(0)444) 236 641.

TOR 1502 Digital Multimeter

The TOR 1502 Digital Multimeter is an easy-to-use, hand-held, high-accuracy meter, all range and functions of which are selected by rotary switch and displayed on a large 23 mm $3^1/_2$ digit liquid crystal display. Among its features are: frequency testing up to 1 MHz, capacitance testing in five ranges up to 99.9 µF; when used in conjunction with any of the optional K-type thermocouples, it has a wide temperature testing range of –20 °C to 1300 °C. With automatic positive and negative indication, diode test, over-range indication, overload protection, low battery indication, continuity beeper and current testing up to 10 A, it is particularly useful for all kinds of service engineering, test management and laboratory applications. The TOR 1502 is supplied complete with test leads and instruction manual.

Full details from TOR Technologies, TOR House, Earl Shilton, Leicester, England LE9 7DG; Telephone +44 (0)455 844 114; Fax +44 (0)455 844 116.

GENERAL NEWS

Piracy on the high CDs

Recent IFPI (International Federation of the Phonographic Industry) figures show that the number of pirated CDs illegally printed or imported into the UK reached 700,000 in 1992. In 1991 there were hardly any.

CD piracy is increasing dramatically throughout Europe – IFPI research suggests there were 13 million illegal discs in 1991 and nearly 19 million in 1992 – and whilst the number of illegal discs sold in the UK last year amounted to only 1% of total sales, that figure is expected to increase greatly this year both here and in Europe.

With the growth of the domestic and commercial multimedia and CD-ROM markets, it can not be long before they, too, become noticeably affected by illegal counterfeiting – with resultant revenue loss to publishers, game-ware producers , film companies, and others.

Disctronics, Europe's leading independent CD manufacturer, have sailed to the rescue with the introduction of a low-cost and effective counter measure which identifies the CD as being genuine and also prevents a disc from being copied. They have announced their ability to print holograms in colour on CDs. This not only provides security – it is virtually impossible to copy a hologram

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ble to copy a hologram without extremely sophisticated (and expensive) equipment – but the discs also look highly attractive. More importantly, it allows the customer to identify the genuine product and avoid buying a sub-standard imitation.

Integrating this hologram into the CD has been developed by Disctronics by placing the optical security information on the same side as the sound/data track. It will also include hidden optical information for the independent evaluation requirements of the trading standards authorities.

Disctronics is one of the pioneers of the CD-ROM and multimedia revolution. Last December, they became the first company in the world to produce Video-CD (the use of digital compact discs with film footage) to the agreed White Book Standard. This allows CDs to be played on all platforms, including Commodore Amiga CD32, CDi and Multimedia PC.

For consumers, this will mean that they can buy any Video-CD player in the knowledge that it will play not only their music CDs, but also open up the huge range of Video-CDs which will be coming on to the market in the next few months – including fiolms, games-ware and music videos.

Further information from Disctronics UK CD-ROM Division, Southwater Business Park, Worthing Road, Southwater, England RH13 7YT. Telephone +44 (0)403 732 302; fax +44 (0)403 732 313.

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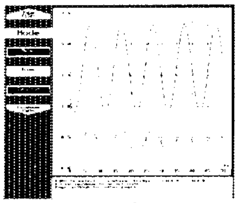

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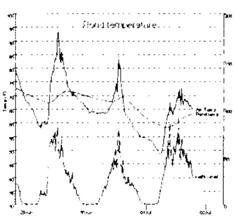

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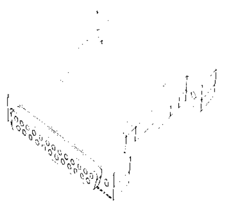

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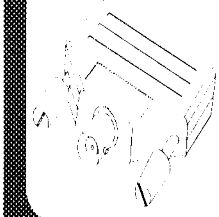

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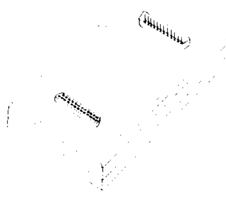

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FROM CONCEPT TO ARTWORK IN 1 DAY

ULTIroute GXR [D:\ULTIMATE\PCBS\CAD_GXR.RTF]
File Parameters View Select Route! Zoom
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ULTIsim [untitled]
File Stimuli Breakpoints View Search Run Zoom Help
Stimuli Run 1 2 3 4 Rel to 2 20.4 ns
ULTIcap V1.50

ULTIboard, one of the leading PC based design systems, is suplied worldwide via a network of ULTImate Technology offices and distributors. ULTIboard's success in the professional design community is primarily due to its superior interactive functionality.

Real Time Placement Aids, Real Time Design Rule Check, Trace Reroute While Move and Trace shove, are all features wich will dramatically reduce your design time.

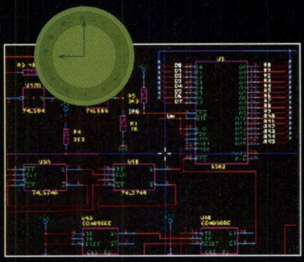
Intergration with ULTIcap guarantees smooth data flow between Schematic and PCB editing and the inclusion of third party netlist interfaces ensures ULTIboard will fit into any design environment.

Another of ULTImate Technology's strengths is our flexible growth path. Users may start with a low cost ULTIboard Challenger Lite and grow, step by step, to a 32-bit Advanced system with Ripup and Retry Autorouting and Digital Simulation.

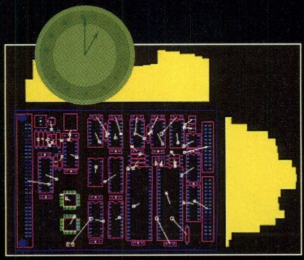
ULTImate Technonlogy also looks after existing users, providing they have valid mainenance subscriptions they will be upgraded to a new system based on their original investment. For instance, a 1987 ULTIboard-DOSsystem has now been upgraded to a 32-bit Advaced system with Windows compliance and 2 Autorouters.

ULTImate Technology not only adds value to your investment in a ULTIboard system but backs it up with the highest quality support from our distributors and offices.

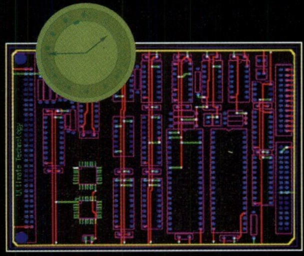
More than
10.000
Users



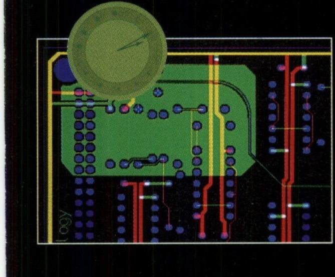
Your design ideas are quickly captured using the ULTIcap schematic design Tool. ULTIcap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTIcap automatically wires them for you. ULTIcap's auto snap to pin and auto junction features ensure your netlist is complete, thereby relieving you of tedious netlist checking.



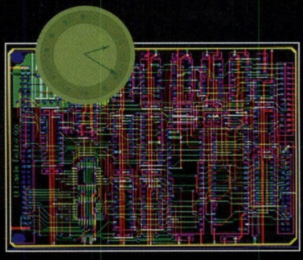
ULTIshell, the integrated user interface, makes sure all your design information is transferred correctly from ULTIcap to ULTIboard. Good manual placement tools are vital to the progress of your design, therefore ULTIboard gives you a powerful suite of REAL-TIME functions such as, FORCE VECTORS, RATS NEST RECONNECT and DENSITY HISTOGRAMS. Pin and gate swapping allows you to further optimise your layout.



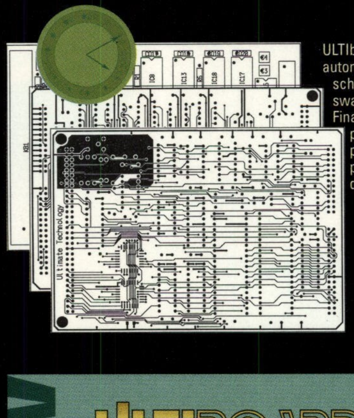
Now you can quickly route your critical tracks. ULTIboard's REAL-TIME DESIGN RULE CHECK will not allow you to make illegal connections or violate your design rules. ULTIboard's powerful TRACE SHOVE, and REROUTE-WHILE-MOVE algorithms guarantee that any manual track editing is flawless. Blind and buried vias and surface mount designs are fully supported.



If you need partial ground planes, then with the Dos extended board systems you can automatically create copper polygons simply by drawing the outline. The polygon is then filled with copper of the desired net, all correct pins are connected to the polygon with thermal relief connections and user defined gaps are respected around all other pads and tracks.



ULTIboard's autorouter allows you to control which parts of your board are autorouted, either selected nets, or a component, or a window of the board, or the whole board. ULTIboard's intelligent router uses copper sharing techniques to minimise route lengths. Automatic via minimisation reduces the number of vias to decrease production costs. The autorouter will handle up to 32 layers, as well as single sided routing.



ULTIboard's backannotation automatically updates your ULTIcap schematic with any pin and gate swaps or component renumbering. Finally, your design is post processed to generate pen / photo plots, dot matrix/laser or postscript prints and custom drill files.

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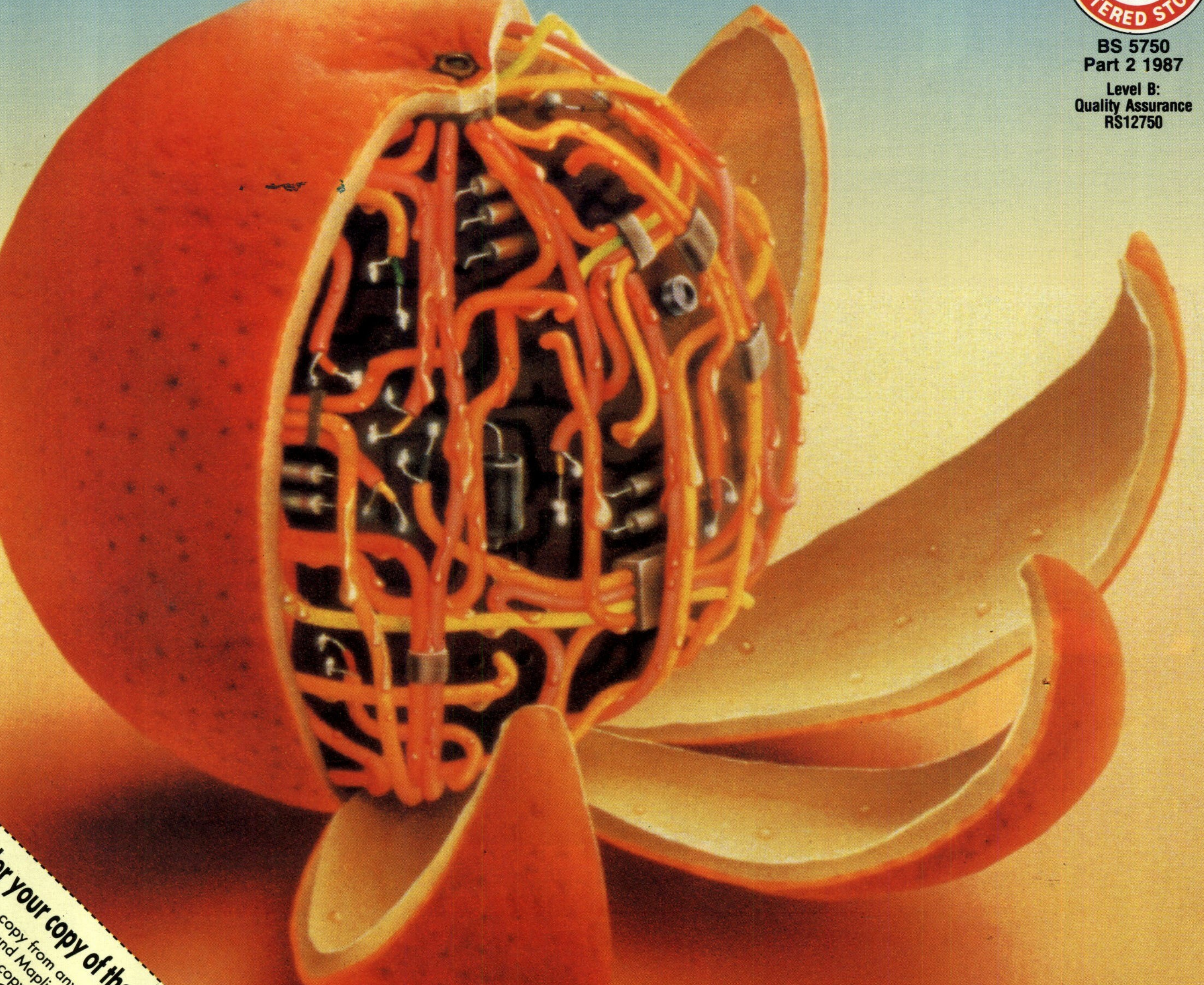

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